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The Geographical Journal

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ADDRESS AT THE ANNIVERSARY MEETING, 31 MAY 1920

Lieutenant-Colonel Sir Francis Younghusband, President

Natural Beauty and Geographical Science

I HAVE something to say which to old-fashioned geographers may appear very revolutionary, and which you may hesitate to accept straightaway. But it has come to me as the result of much and varied geographical work in the field; of listening to many lectures before this Society; and of composing this Address and five lectures for you, firstly, as far back as 1888, on my journey across Central Asia from Peking to India; secondly, on my journey to Hunza and the Pamirs; thirdly, on Chitral; fourthly, on my mission to Tibet; and fifthly, on the Himalaya. And I expect when you come to think over what I have now to say you will find that, after all, my conclusions are not anything desperately revolutionary but something quite obvious and natural.

What I want to lay before you for your very earnest consideration is this—that we should take a profounder and broader view of Geography, of its fundamental conception, and of its scope and aim, than we have hitherto taken; and should regard the Earth as *Mother*-Earth, and the *beauty* of her features as within the purview of geography.

I will state my case as clearly and briefly as I can. Geography is a science. Science is learning, knowing, understanding. The object of geographical learning, knowing, understanding is the Earth. We must first, then, have a true conception of what the Earth really is. And next we must be certain in our minds as to what is most worth knowing about it.

To begin with our conception of the Earth. At the dawn of geography it was believed to be a flat disc. Later it was discovered to be a sphere. Then it was found to be not a hard solid sphere like a billiard ball, but to be hard only on the surface, and within to be quick with fervent heat. Now it is coming to be regarded as spirit as well as body—as in its essential nature spiritual rather than material.

When we get as far back as science is able to take us we find that the ultimate particles of which the Earth is made up are not minute

specks of some substance or material, but are simply centres of radiant energy. Even with a microscope of infinite power we should never be able to see one, like we see a grain of pollen or a grain of sand. And if we had fingers of infinite delicacy, we should never be able to take one up between the forefinger and thumb and feel it. These ultimate particles are invisible and intangible. Nothing could be less substantial. And we find further that, inconceivably minute as they are, they *act of themselves* under the mutual influence of another. The electrons are not like shot which have been heaped together by some outside agency, and which roll about the floor if some one outside gives them a push, but which will otherwise remain immobile. They congregate together of their own inner prompting. They are like a swarm of midges or bees in which each individual acts on its own impulsion, and, in the case of bees, all together form themselves into a definite organization with a collective spirit of its own. The Earth is indeed influenced by its parent the Sun, and acts in accordance with the same laws and is swayed by the same impulses as govern the whole universe, of which it is a minute though highly important mite. But the point is that the Earth is not something like a lump of clay which a potter takes in his hands and moulds into a ball. The Earth moulds itself from activities that it contains within itself.

Running through the whole mighty swarm of electrons we call the Earth is a tendency to order, organization and system. The myriad millions of ultimate particles in their all-togetherness and from their inter-action upon one another become possessed of an imperative urge towards excellence. The electrons group themselves into atoms; the atoms clump themselves together into molecules; the molecules combine into chemical compounds, and these into organisms of ever-increasing size and complexity. So in the process of the ages there came into being, from out of the very Earth itself, first, lowly forms of plants and animals, then higher and higher forms exhibiting higher and higher qualities, till the flowers of the field, the animals, and man himself came into existence.

And now we reach the point I wish to make. If this account of the Earth which physicists and biologists give us be true, then we geographers should take a less material and a more spiritual view of the Earth than we have done, and should, like primitive people all the world over, regard her as Mother-Earth, and recognize our intimate connection with her. Primitive peoples everywhere regard the Earth as alive and as their Mother. And so intensely do they feel this liveness that many will not run the plough through the soil from dislike of lacerating the bosom of Mother-Earth. They see plants and trees spring up out of her, and these plants and trees providing them with fruits and seeds, leaves and roots, upon which to live. And they quite naturally look upon her as their Mother. And we men of the more advanced races have still more cause to consider her as our Mother, for we now know that not only the plants and trees but

we ourselves sprang from her—as indeed we are nourished by her daily, eating her plants or the animals which feed on her plants. And as we judge of a lily, not by its origin, the ugly bulb, but by the climax, the exquisite flower; so we should not judge of the Earth by its origin, the fiery mist, but by its issue—ardent human fellowship. And if we thus judge her we shall find her a mother worthy of our affection.

So the first point I have to put before you is that we geog raphers should regard the object of our science not as a magnified billiard-ball, but as a living being—as Mother-Earth. Not as hard, unimpressionable, dull, and inert, but as live, supple, sensitive, and active—active with an intensity of activity past all conceivability. Yet with no chaotic activity, but with activity having coherence and direction, and that direction towards excellence.

Now as to what we ought to know about the Earth. While Geology concerns itself with its anatomy, Geography, by long convention, restricts its concern to the Earth's outward aspect. Accordingly, it is in the face and features of Mother-Earth that we geographers are mainly interested. We must know something of the general principles of geology, as painters have to know something of the anatomy of the human or animal body. But our special business as geographers is with the outward expression. And my second point is that the characteristic of the face and features of the Earth most worth learning about, knowing, and understanding is their beauty; and that knowledge of their beauty may be legitimately included within the scope of geographical science.

It may be argued, indeed, that science is concerned with quantity—with what can be measured—and that natural beauty is quality which is something that eludes measurement. But Geographical science, at least, should refuse to be confined within any such arbitrary limits and should take cognizance of quality as well as quantity. This is my contention. I am not maintaining that the actual enjoyment of the natural beauty of the Earth should be regarded as within the scope of geographical science, though this Society as a social body might well participate in such enjoyment. Enjoyment is feeling, whereas science is knowing; and feeling and knowing are distinct faculties. We can casily see the distinction. We may be travelling to Plymouth to embark for South Africa on some absorbing enterprise, and be so engrossed with thoughts of the adventure before us as to be unable to enjoy the famed west country through which the train is passing, though all the time we were quite aware in our minds of its beauty. We are not actually enjoying the beauty, though we know quite well that it is there. On another occasion we may be returning after long absence in countries of far different character; our minds may be free from any disturbing thoughts; and we may be in a mood to enjoy to the full every beauty we see. England will then seem to us a veritable

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It may be argued, indeed, that science is concerned with quantity—with what can be measured—and that natural beauty is quality which is something that eludes measurement. But Geographical science, at least, should refuse to be confined within any such arbitrary limits and should take cognizance of quality as well as quantity. This is my contention. I am not maintaining that the actual enjoyment of the natural beauty of the Earth should be regarded as within the scope of geographical science, though this Society as a social body might well participate in such enjoyment. Enjoyment is feeling, whereas science is knowing; and feeling and knowing are distinct faculties. We can casily see the distinction. We may be travelling to Plymouth to embark for South Africa on some absorbing enterprise, and be so engrossed with thoughts of the adventure before us as to be unable to enjoy the famed west country through which the train is passing, though all the time we were quite aware in our minds of its beauty. We are not actually enjoying the beauty, though we know quite well that it is there. On another occasion we may be returning after long absence in countries of far different character; our minds may be free from any disturbing thoughts; and we may be in a mood to enjoy to the full every beauty we see. England will then seem to us a veritable

garden, the greenness of everything, the trimness of the hedges, the sheets of purple hyacinths, and some still remaining primroses, will startle us with joy, though we have long been aware of their beauty. This time we both know and enjoy the natural beauty. We see from this instance the distinction between knowing natural beauty and enjoying it. I am not claiming more than that *knowing* natural beauty—being aware of it—is part of geography. But I *am* claiming liberty to extend our knowing up to the extreme limit when it merges into feeling.

What we have now to consider is the value of this natural beauty. A region may be flat or mountainous, dry or wet, barren or fertile, useful or useless for either political or commercial purposes. But it is not its flatness or ruggedness, or its utility or inutility for political or commercial purposes, that we may find in the end is the most noteworthy characteristic, but its beauty—its own particular beauty. The conventional gold or oil prospector, or railway engineer, or seeker for sites for rubber or coffee plantation, or pasture lands for sheep and cattle, may not bother his head about the beauty of the forests, the rivers, the prairies, and the mountains he is exploring. He is much too absorbed in the practical business of life to be distracted by anything so fanciful—as he thinks. Yet even he does see the beauty, and long afterwards he finds it is that which has stuck most firmly in his mind. And when he has unthinkingly destroyed it, future generations lament his action and take measures to preserve what remains. Advertisements, also, show us daily that nearly all countries—and it seems more especially new countries like Canada and New Zealand—regard natural beauty as one of their most valuable assets. And the reason why the natural beauty of the Earth is deemed so valuable a characteristic of its features is not hard to understand when we come to reflect. It is because beauty is a quality which appeals to the universal in man—appeals to all men for all time, and appeals to them in an increasing degree. It is something which all men can admire and enjoy. And the more they enjoy it the more they want to get others to share in their enjoyment. Also the more natural beauty they see the more, apparently, there is to see. Poets in their poems, and painters in their pictures, are continually pointing out to us less keen-sighted individuals new beauties in the features of the Earth. The mineral wealth of the Earth has its limits; even the productivity, though perennially renewed, is not unbounded. But the natural beauty is inexhaustible. And it is not only inexhaustible: it positively increases and multiplies the more we see of it and the more of us see it. So it has good claim to be considered the most valuable characteristic of the Earth.

And if beauty should prove to be its most valuable characteristic, it follows that knowledge of it is the knowledge about the Earth which is most worth having. It will certainly be the case that knowledge of other characteristics may be of more value to particular men for a special purpose for the time being. If an engineer has to build a railway,

knowledge of the exact height above sea-level of various points and of the general configuration of the ground is of more value than knowledge of its beauty. But for the engineer himself, when he is not thinking of his railway, and for mankind in general, knowledge of the beauty may be the more valuable kind of knowledge.

For years I was employed in exploring the region where three Empires meet, where the Himalaya, the Hindu Kush, and mountains which form the Roof of the World converge. I had to report on the extent to which it afforded a barrier against the advance of Russia towards India, and where in it would lie the most appropriate boundary between India and Russia, between India and China, and between Russia and China. What I learned of that region as a barrier against invasion was of more value to the Viceroy and Commander-in-Chief in India and the political and military authorities in England in the discharge of their official duties than what I learned of its beauties. But this utility of the region as a military barrier is not the characteristic which has most value to men in general. What to them has most value is its beauty—the awful beauty of its terrific gorges and stupendous heights. And it is knowledge of this beauty which is most worth having, and which has most geographical value.

Besides exploring the far region beyond Kashmir I was also employed for years in exercising a general supervision over the entire administration of Kashmir itself. Reports from experts used to come to me containing every description of geographical knowledge. Surveyors would send in maps for general purposes, for the construction of roads and railways, for the delimitation of village boundaries, and for registering the ownership of individual fields. Geologists would report on the crustal relief (as the features of Mother-Earth are inelegantly termed). Forestry, agricultural, and botanical experts would report on the productivity of the soil, on the plants and trees which are or might be grown, and on their present and possible distribution. Mineralogists would report on the minerals, their distribution and the possibility of commercially exploiting them. Every aspect of geographical science was presented to me. And each particular kind of knowledge for its own particular purpose was highly valuable. But the point I would wish to make is that my geographical knowledge of Kashmir would have been incomplete—and I would have been wanting in knowledge of its most valuable characteristic—if I had had no knowledge of its beauty. I might have had the most precise knowledge about the form and structure of the crustal relief of this portion of the earth, of the productivity of the soil, of the distribution of its population, and of animals and plants, and about the effect of the crustal forms on the animals and plants, and of the animals and plants upon the crustal forms and of all upon man, and of man upon them all; but if I had had no knowledge of the beauty of these crustal forms and of the influence which their beauty has upon man, I should not have known what was most worth knowing about Kashmir. My geographical knowledge of that country would have been wanting in its most important particular.

These illustrations will, I hope, make clear what I mean when I urge that beauty may be the most valuable characteristic of the Earth's features, and that the scope of geography should certainly be extended to include a knowledge of it.

And there should be less hesitation in accepting the latter half of this conclusion when we note that natural beauty affects the movements of man, and that man is having an increasing effect upon natural beauty—spoiling it in too many cases, improving it in many others, but certainly having an effect upon it. There is thus a quite definite relation between man and natural beauty, and it should therefore be within the scope of geography to take note of this relationship. To an increasing degree man now moves about in search of new natural beauty or to enjoy it where it has been already found. From all over the world men flock to Switzerland, drawn there by its beauty. Here at home they go to the Thames Valley, or Dartmoor, or the coast of Cornwall, or North Wales, or the Highlands, simply to enjoy the natural beauty. And railway companies and the Governments of Canada, Australia, and New Zealand, think it worth while to spend large sums of money in publishing pictures of the beauty of the countries in which they are interested in order to attract holiday-makers or home-seekers to them.

And here, as in other cases, man now is not content to be an impassive spectator and to be entirely controlled by his surroundings. He does not allow the "crustal relief" to have the upper hand in the matter. He will not admit that all he has to do is to adapt himself to his surroundings. That servile view of our position in the Universe is fast departing. We are determined to have the ascendency. And much as we admire the beauty of the Earth we set about improving it. We fail disastrously at times, I allow. But sometimes unconsciously, and sometimes deliberately, we succeed. We have in places made the Earth more beautiful than it was before we came, and we have certainly shown the possibility of this being done. From what I have seen in uninhabited countries I can realize what the river-valleys of England must have been like before the arrival of man—beautiful, certainly; but not *so* beautiful as now. They must have been an unrelieved mass of forest and marsh. Now the marshes are drained and turned into golden meadows. The woods are cleared in part and well-kept parks take their place, with trees specially selected, pruned, and trim, and made to stand out well by themselves so that their umbrageous forms may be properly seen. Gardens are laid out, the famous lawns of England are created, and flowering and variegated shrubs from many lands are planted round them. And homes are built—the simple homes of the poor and the stately homes of the rich—which in the setting of trees and lawns and gardens add unquestionably to the natural beauty of the land. St. James' Park, with its lake, its well-tended trees, its daisy-covered lawns, its flower-beds, its may and lilac, laburnum, and horse-chestnut, and with the towers of Westminster

Abbey and the Houses of Parliament rising behind it, is certainly more beautiful than the same piece of land was two thousand years ago in its natural condition.

What has been done in this respect in England is only typical of what is done in every country and of what has been done for ages past. The Moghul emperors, by the planting of gardens on the borders of the Dal Lake in Kashmir, added greatly to its beauty. And the Japanese are famous for the choice of beautiful surroundings for their temples and for the addition which they themselves, by the erection of graceful temples and by properly cared-for trees and gardens, make to the natural beauty of the place.

So man is both affected by the beauty of the Earth's features and himself affects that beauty. And this relationship between man and the natural beauty of the Earth is one of which Geography should take as much cognizance as it does of the relationship between man and the productivity of the earth.

But natural beauty is manifested in an innumerable variety of forms. The whole beauty is never manifested in any one particular feature or region, but each has its unique aspect. Each feature has its own peculiar beauty different from the beauty of any other feature. And what men naturally do, and what I would suggest Geography should deliberately do, is to compare the beauty of one region with the beauty of another so that we may realize the beauty of each with a greater intensity and clearness. We can compare the beauty of Kashmir with the beauty of Switzerland and California. And the comparison will enable us to see more clearly and to appreciate the distinctive elements which make up the peculiar beauty of each of those countries. It has been frequently noticed that people who have always lived in the same place are unable to see its full beauty. The inhabitants of the Gilgit frontier when I first went among them, had never left their mountains, and were altogether ignorant of the special grandeur of their beauty. They thought all the world was just the same. But men who have seen many varieties of natural beauty and have taken pains to compare the varieties with one another become trained to see more beauty in each feature. Fresh discoveries of beauty are thus made, and our knowledge of the beauty of the Earth is thereby increased.

What I hope, then, is that this Society should definitely recognize that learning to see the beauty in natural features and comparing the peculiar beauties of the different features with one another is within the scope of geography, and will indeed become its chief function. I should like to see the tradition established and well known and recognized that we encourage the search for natural beauty, and look upon the discovery of a new region which possesses special beauty, and the discovery

of a new beauty in a region already well known, as among the most important geographical discoveries to be made. In this matter I trust our Society will take the lead. Englishmen are born lovers of natural beauty and born travellers. The search for natural beauty ought, therefore, to be a congenial task for this Society. As I have tried to make clear, we cannot really know and understand the Earth—which is the aim of Geography—until we have seen its beauties and compared the varying beauties of the different features with one another and seen how they affect man and man affects them. We are constituted as a Society for the purpose of diffusing geographical knowledge, and I trust that in future we shall regard knowledge of the beauty of the Earth as the most important form of geographical knowledge that we can diffuse.

When I was writing out the lecture which I was invited to give before the Society on "The Geographical Results of the Tibet Mission" I could not resist devoting special attention to the natural beauty of Tibet. But as I read the manuscript through I feared that this attention to beauty would be regarded by our Society as a lapse from the narrow path of pure geography, and that I should be frowned upon in consequence and not regarded as a serious geographer. I ought, I feared, to have devoted more attention to survey matters, to the exact trend of the mountains, and the source and course of the rivers. But looking back now I see that my natural instinct was a right one—that a knowledge of the beauties of Tibet was not only one geographical result of the Mission, but the chief geographical result; and that in fact I ought to have paid not less but more attention, both in Tibet to noting its beauties in all their multitudinous variety, and in writing my lecture to expressing with point and precision what I had seen, so that you might share it with me, and learn what is the most valuable characteristic of Tibet.

When the new tradition is established, and travellers become aware that we regard knowledge of natural beauty as within the scope of our activities, the error into which I fell will be avoided. We shall think travellers barbaric if they continue to concern themselves with all else about the face of the Earth except its beauty. We shall no longer tolerate a geographer who will learn everything about the utility of a region for military, political, and commercial purposes, but who will take no trouble to see the beauty it contains. We shall expect a much higher standard of him. We shall expect him to cultivate the power of the eye till he has a true eye for country—a seeing eye; an eye that can see into the very heart and, through all the thronging details, single out the one essential quality; an eye which can not only observe but can make discoveries. We shall require him to have the capacity for discriminating the essential from the unessential, for bringing that essential into proper relief and placing upon it the due emphasis. When he thus has true vision and can really see a country, and when he has acquired the capacity for expressing either in words or in painting what he has seen,

so that he can communicate it to us, then he will have reached the standard which this Society should demand. And this is nothing less than saying that we expect of him that he should have in him something of the poet and the painter.

Careless snap-shotting in the field and idle turning on of lantern slides at our meetings will no longer satisfy us. A traveller if he is going to photograph must spend the hours which a real artist would devote to discovering the essential beauty of a scene, and to composing his picture before he dreams of exposing his plate. But we want more than photographs: we want pictures to give that important element in natural beauty—the colour. And we want pictures painted in words as well as on canvas. Not shallow rhapsodizing of the journalese and guide-book type, but true expression in which each noun exactly fits the object, each epithet is truly applicable, and each phrase rightly turned, and in which the emphasis is placed on the precisely right point, and the whole composed so as distinctly to bring out that point.

Then in time we shall gather together the most valuable knowledge about the Earth. And when a stranger from a far land comes to us to know about any particular country, we shall be able to provide him with something worth having. When an Australian comes to England and wishes to know its essential characteristics, we shall do something more than hand him over maps and treatises on the orography and hydrography, the distribution of rainfall, of plants and animals, and the population. We shall regard ourselves as having omitted to point out to him the essential characteristic of the land from which Englishmen have sprung and in which they dwell if we have not shown him the beauty of its natural features. We shall give him the maps as aids to finding his way about, and we shall give him the treatises. But we shall tell him that these are only aids for special purposes, and that if he is really to understand England he must know its beauty in its many aspects. He will then have the geographical knowledge of chief value about England.

A project in which the Society is now interested affords an excellent opportunity of applying the principles I have been trying to persuade you to adopt. The most prominent feature of this Earth, and the feature of most geographical interest, is the great range of the Himalaya mountains. In this range the supreme summit is Mount Everest, the highest point on the Earth, 29,002 feet above sea-level. Attempts have been made to ascend the second highest mountain, K_2, 28,278 feet, notably by the Duke of the Abruzzi. Colonel Hon. Charles Bruce, Major Rawling, and others have had in mind the idea of ascending Mount Everest itself. And for more than a year past both the Alpine Club and this Society have been definitely entertaining the idea of helping forward the achievement of this object. We hope within the next

few years to hear of a human being standing on the pinnacle of the Earth.

If I am asked, What is the use of climbing this highest mountain? I reply, No use at all: no more use than kicking a football about, or dancing, or playing on the piano, or writing a poem, or painting a picture. The Geologist predicts to a certainty that no gold will be found on the summit, and if gold did exist there no one would be able to work it. Climbing Mount Everest will not put a pound into any one's pocket. It will take a good many pounds out of people's pockets. It will also entail the expenditure of much time and necessitate the most careful forethought and planning on the part of those who are organizing the expedition. And it will mean that those who carry it out will have to keep themselves at the very highest pitch of physical fitness, mental alertness, and moral courage and endurance. They will have to be prepared to undergo the severest hardships and run considerable risks. And all this, I say, without the prospect of making a single penny. So there will be no *use* in climbing Mount Everest. If the ascent is made at all it will be made for the sheer love of the thing, from pure enjoyment—the enjoyment man gets from pitting himself against a big obstacle.

But if there is no *use*, there is unquestionably *good* in climbing Mount Everest. The accomplishment of such a feat will elevate the human spirit. It will give men—and especially us geographers—a feeling that we really are getting the upper hand on the Earth, that we are acquiring a true mastery of our surroundings. As long as we impotently creep about at the foot of these mighty mountains and gaze on their summits without attempting to ascend them, we entertain towards them a too excessive feeling of awe. We are almost afraid of them. We have a secret fear that they, the material, are dominating us, the spiritual. But as soon as we have stood on their summit we feel that *we* dominate *them*—that we, the spiritual, have ascendency over them, the material. And if man stands on Earth's highest summit he will have an increased pride and confidence in himself in his struggle for ascendency over matter. This is the incalculable good which the ascent of Mount Everest will confer.

We who have lived among the peoples of the Himalaya are better able than most to appreciate how great this good is. We have seen how tame and meagre is their spirit in comparison with the spirit of, for example, the Swiss, or French, or Italian inhabitants of the Alps; and in comparison with what men's spirit ought to be. They have many admirable qualities, but they are fearful and unenterprising. Contact with them brings home to us what a spirit of daring and high adventure means to a people. And we are impressed with the necessity of taking every step possible to create, sustain, and strengthen this spirit in a people and in the human race generally. The ascent of Mount Everest, we believe, will be a big step in that direction.

The actual climbing of this mountain this Society will leave in the

hands of the Alpine Club, who have special experience in mountain climbing. But the reconnaisance and mapping of the mountain and its neighbourhood will fitly remain with us. And here we reach the point where the principles I have been offering for your consideration might be applied. Were it not that the size of the first party will have to be limited on account of transport and supply difficulties, I should greatly like to have a poet or a painter, or anyhow a climber like Mr. Freshfield with a poetic soul, a member of it. For I say quite deliberately and mean quite literally that the geography of Mount Everest and its vicinity will not be complete until it has been painted by some great painter and described by some great poet. Making the most accurate map of it will not be completing our knowledge of it. The map-maker only prepares the way—in some cases for the soldier or the politician or the engineer—in this case for the geologist, the naturalist, and above all for the painter and poet. Until we have a picture and a poem—in prose or verse—of Mount Everest we shall not really know it; our geography will be incomplete, and, indeed, will lack its chief essential.

The Duke of the Abruzzi, in his expedition to the second highest mountain in the world, took with him the finest mountain photographer there is—Signor Vittoria Sella—and he brought back superb photographs, for he is a true artist with a natural feeling for high mountains. But I have seen the very mountains that he photographed, and when I look at these photographs—the best that man can produce—I almost weep to think how little of the real character of great mountains they communicate to us. The sight of the photographs wrings me with disappointment that it was a photographer and not a painter who went there. Here in Europe are artists by the score painting year after year the same old European scenes. And there in the Himalaya is the grandest scenery in the world, and not a painter from Europe ever goes there—except just one, the great Russian Verestchagin, whose pictures, alas! are now buried somewhere in Russia. The Indian services might do something, and they have indeed produced one great painter of Himalayan scenery, Colonel Tanner. But the services are limited, and it is to Europe that we must mainly look.

On the first expedition to Mount Everest it may be only possible to send a photographer. But this will be a pioneering expedition to open the way, at least, for the painter. And then we may have Mount Everest pictured in all her varied and ever-varying moods, as I have, from a distance, seen her for three most treasured months. Now serene and majestic; now in a tumult of fury. Now rooted solid on earth; now hung high in the azure. Now hard and material; now ethereal as spirit. Now stern and austere—cold, and white, and grey; now warm and radiant and of every most delicate hue. Now in one aspect, now in its precisely opposite, but always sublime and compelling; always pure and unspotted; and always pointing us starward.

These are the pictures—either by painter or by poet—that we want.

And they can only be painted by one who has himself gone in among the mountains, confronted them squarely, braced himself against them, faced and overcome them—realized their greatness, realized also that great as they are he is greater still.

And this that we want of the greatest natural feature of the Earth is only typical of what this Society should require in regard to all Earth's other features in order to make our geography complete. As men have pictured the loveliness of England, the fairness of France, the brilliance of Greece, so we want them to picture the spaciousness of Arabia, the luxuriance of Brazil, and the sublimity of the Himalaya. For not till that has been done will our geography be complete. But when that has been accomplished and the quest for beauty is being pushed to the remotest lands and Earth's furthest corners, even the British schoolboy will love his geography, and our science will have won its final triumph. At nothing less, then, than the heart of boy should our Society deign to aim.

So much for the idea which I wish to make the main feature of this address. I must now, in conclusion, briefly review our proceedings during this session. In it we have begun to enjoy some of the occasional beneficent effects of the war, and among the papers which have excited most interest were several that arose directly from it. The outstanding event was the great meeting at the Central Hall, which was addressed by General Sir Frederick Sykes on a topic of the highest Imperial interest, the Air Routes of the Empire, and was honoured by the presence of our Vice-Patron, The Prince of Wales. On another occasion we enjoyed the hospitality of Sir Ernest Shackleton at the Philharmonic Hall, and were able to congratulate him on his magnificent leadership.

His Majesty's Government having withdrawn from us the hospitality of the Theatre in Burlington Gardens which we have enjoyed for so many years, for the present we are meeting in this hall, which, I confess, is not in all ways well suited for our meetings, particularly in the platform arrangements. We all look forward to the possibility of building our own hall within the next few years, but we could wish that the prospects of an immediate start were more favourable. Until the Fellows attending our meetings are able at the same time to enjoy, and to commend to their guests, the many attractions of the Society's house, we cannot hope to make our evening meetings the distinctive events that they should be in the scientific life of London. In present conditions we can neither supplement the interest of the meeting by an exhibition of related maps and pictures, nor can we provide, as we should wish to do, for the bodily refreshment of the meeting. But the Council keep steadily before them the necessity of completing the great scheme which was inaugurated by the purchase of Lowther Lodge more than seven years ago, and they feel

assured that if, under the sadly changed conditions of cost, it is necessary to make a further appeal to friends of the Society, that appeal will meet with a ready response.

Were it not for the very satisfactory vitality of the Society, and the considerable additions to its Fellowship within the last eighteen months—additions which go far to remedy the wastage of war—the Council would have been compelled ere now to make proposals to the Society for some method of meeting the very greatly increased cost of the publications, the staff, and the maintenance of the house. I realize to the full the difficulty of raising the subscription to the Society, and no such general proposal will be made unless it is absolutely necessary; but it has been found impossible to make income and expenditure meet during the last year, and I am not sure that the gradual substitution of members paying three pounds a year for those elected before 1908 and paying two pounds a year will, with the advance in numbers of Fellows, restore the position. If it does not, I shall have to make proposals to you for meeting the situation.

In conclusion I would like, on your behalf, to congratulate our Secretary on the distinction of a Companionship of the Order of the British Empire which has been conferred upon him. Mr. Hinks has done much to keep a high standard in every activity of our Society. We rely upon him continually to raise that standard, for nothing but the best is good enough for us.

THE AFRICAN RIFT VALLEYS

Prof. J. W. Gregory, F.R.S.

Read at the Meeting of the Society, 5 January 1920.

THE discovery of Lake Rudolf in 1888 led Suess to the conclusion, which he announced in 1891, that the southern continuation of the fractures of the Jordan Valley and Red Sea is along the lake chain in East Africa, and not along the coast. As his view represented that many of the chief East African valleys and lake basins had been caused directly by faulting, it was not in accordance with the then orthodox view that land valleys are nearly always due to erosion. I therefore gladly availed myself of the opportunity in 1892–3 to visit East Africa in order to examine the structure and origin of its system of valleys. Observations at the highest part of the main valley, where it crosses British East Africa from Lake Baringo to Lake Naivasha, convinced me that it was due to the sinking of the floor between parallel fractures, and that therefore Suess's view was correct, apart from some modifications as to the age and history of the valley.

Since that date much additional evidence * has been obtained; maps of most of the area are available; dates suggested in 1893 on physiographic inference have been settled by the direct evidence of fossils, and the extension of the Rift Valley has been traced south of the Zambezi. As I have recently had the opportunity, thanks to H.E. General Sir Edward Northey, Governor of British East Africa, to re-examine some of the country, and to visit some parts of it that I had not seen previously, in company with the Hon. C. W. Hobley, C.M.G., the Hon. W. Macgregor Ross, and Captain H. L. Sikes, it may be useful to restate the evidence as to the range of the African Rift Valley system, as to its age and origin, and its relations to the major contemporary earth-movements in other parts of the world.

Part I.

The Nature of Rift Valleys.—That this valley was made by the subsidence of its floor between two more or less parallel series of fractures has been accepted, as far as I know, by every geologist who has visited it. Dr. Ball (1912, p. 355), however, as a corollary to his views on the gulf of Suez, has expressed doubt as to the origin of the Red Sea trough by faulting. Unlike ordinary valleys, which are formed by the removal piecemeal by rivers or wind of the material that once filled them, this valley was caused by the material sinking in mass, so that what is now its floor formerly stood level with the highlands on each side.

For this type of valley I suggested the term Rift Valley, not implying that the whole valley was formed by the two sides being simply pulled apart, but as a breach due to a subsidence between two series of rents. The term "rift" seems to me wider than "rent." Rents are one variety of rifts. Originally the term "rift" may have meant a space formed by splitting; but according to the New English Dictionary, its use for a split, crack, or rent is now somewhat rare. That dictionary gives as its second definition of rift, "a cleft, fissure, or chasm in the earth." When Scott in 'The Lady of the Lake' (316), says of the hills of Skye:

> "The grisly gulfs and slaty rifts
> Which seam its shiver'd head,"

and when Bryant sings of

> "The rifted crags that hold
> The gathered ice of winter,"

and Shelley in 'Arethusa' speaks of

> "Up through the rifts
> Of the mountain clifts,"

they do not mean gaps made by the rocks having been rent asunder. Certainly Ruskin does not when referring ('Modern Painters,' 4, ch. v.,

* The chief literature is enumerated in the excellent summary in M. de Margerie's edition of Suess ('La face de la Terre,' vol. 3, pt. 1913, pp. 957-986), which also reprints some important maps not easily accessible.

xix., 27) to rifts made by glaciers; and the term is accepted in a general sense by J. Wright ('English Dialect Dict.,' 1904, vol. 5, p. 106) in his definition of rift—"A cleft in a rock; a long deep fissure." Hence it seems that the term "rift valley" does not necessarily mean clefts formed by rocks being torn apart as by landslips or earthquakes, and is justifiable for valleys due to subsidence between a pair of rents. The term seemed more appropriate than "trough valley," which moreover is used (in the sense of "trogthal") for a valley rendered trough-shaped by glacial action.

The Course of the Great Rift Valley.

Such rift valleys are known in many parts of the world, but that of East Africa may justly be called the Great Rift Valley, as it extends from northern Palestine to southern Africa. It includes seven chief sections: that in Palestine and Sinai; the Red Sea and its branches, the gulfs of Suez, Akaba, and Aden; in Abyssinia; in British East Africa; in German East Africa; the southernmost section from Lake Nyasa to the Sheringoma Plateau; and the western branch including Tanganyika and the Upper Nile.

The Rift Valley begins to the north in Palestine. That the canyon of the Jordan and Dead Sea lies along fractures has long been well established. For example, a section by Prof. Hull (1889, p. 106, and plates, sect. 4) shows that Mount Hor consists of a mass of granite capped by Cretaceous limestones that also lie at its foot, against which they have been dropped by a fault with a downthrow of at least 5000 feet. It is true that Lartet and Hull were disposed to attribute the valley to movement along a single fracture; but later authorities have shown that the subsidence happened between parallel fractures. Thus Blanckenhorn's sections (*e.g.*, 1914, pp. 88, 97) represent both the Jordan Valley and the Dead Sea as a trench left by a strip of the limestones having sunk into the basement of older rocks, which are exposed in places on the walls of the valley. Prof. Bonney (1904, p. 577) demurs to the term "rift valley" being applied to the Jordan Valley, as its fault scarps have been worn away by denudation; but he agrees that it was formed by subsidence between parallel faults.

The general character of the Jordan–Dead Sea Valley is well shown in the beautiful relief model of Palestine in the entrance hall of the Society's house. Traced to the north, the parallel faults of the Jordan change into a divergent series, and the single rift valley of the Jordan splits up into a series of smaller valleys which taper out in front of the transverse fold-mountains of the Taurus. South of the Dead Sea, the Rift Valley passes over a divide at the height of 660 feet, and continues down the Wadi Araba to the gulf of Akaba, forming a deep cleft between the plateaus of Sinai and Edom. The fiord-like character of the gulf of Akaba was remarked by Prof. Bonney (1873, p. 395). Its valley is described as a rift valley by Dr. Hume, Director of the Geological Survey of Egypt, who

has shown, moreover, that parallel to it in Eastern Sinai there are five valleys which he regards as also rift valleys (Hume, 1901, pp. 198–199). In the case of two, the evidence is conclusive; in the case of the other three, it is strong though inferential. In Sinai the north and south movements along the Rift Valley have been crossed by east and west movements, which have had a conspicuous influence in Egypt. The intersection of these different movements has produced the rectangular branching which gives the valley system of Eastern Sinai its fiord-like plan (Gregory, 1913, p. 227).

South of Sinai, the structure of the Rift Valley is again simpler. The Red Sea trough is a denuded rift valley defined by north-west to south-east faults. According to Blanckenhorn (1914, pl. 1) its coasts follow two lines of fractures. According to Cyril Crossland (1913, pp. 122, 155), not only are some of its narrow harbours or "khors" indentations due to side cracks, but the main trough was formed as a rift valley of most pronounced character, and due to a downthrow of 11,000 feet.

The trough cuts across the desert girdle of the eastern hemisphere and separates the plateaus of Nubia and of Arabia, in both of which the foundations consist of ancient crystalline rocks. In the northern part of the Red Sea the movements have not been closely associated with volcanic eruptions, for although wide sheets of lava and well-preserved craters occur on the Arabian plateau, they are some distance back from its edge.* At the southern end of the Red Sea, however, volcanoes have been very active, and have built up a chain of islands along the fairway, and numerous extinct cones along both shores.

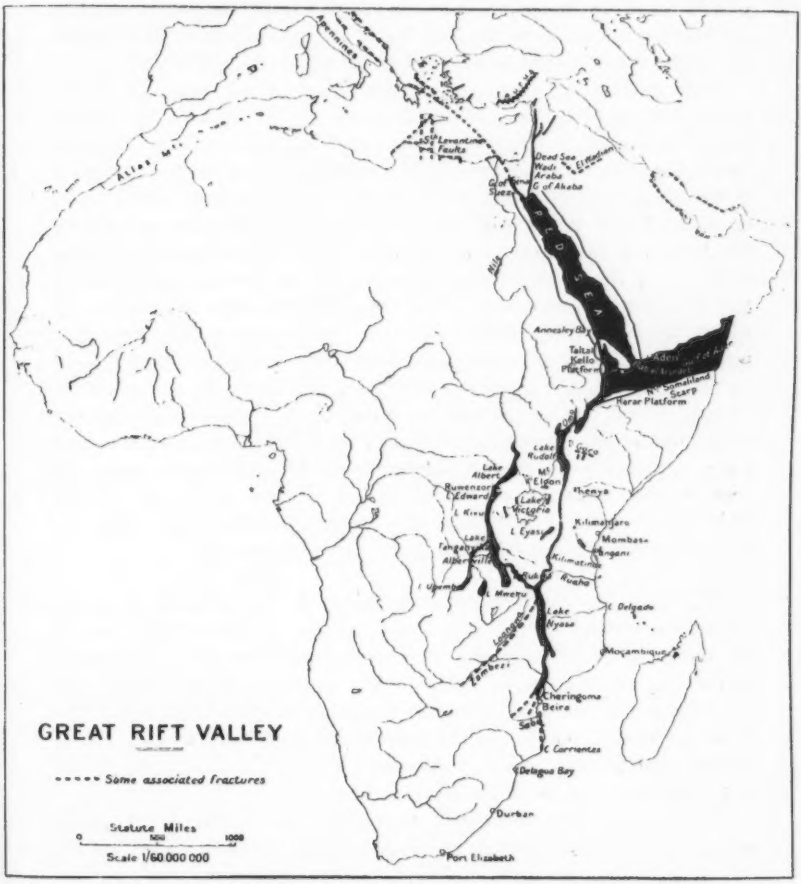
The main trough of the Red Sea is continued north-westward as the gulf of Suez, which has cut off the eastern end of the ranges between Suez and Cairo and disappears under the alluvial deposits of northern Egypt. Doubt as to the origin of the gulf of Suez has been introduced by Dr. Ball during the discussion whether the Nile valley in Lower Egypt may be a rift valley. That the Nile near Cairo occupies a valley due to down faulting was remarked by Sir William Dawson (1884, p. 290) and Beadnell (1901, p. 28). Colonel Lyons (1906, pp. 10, 294) and Dr. Blanckenhorn (1902, pp. 703–709) have explained the subsidence as a rift valley, though the first author is said to have altered this opinion, and the last in a later memoir (1910, p. 430) represents it as so old and denuded as not to be a typical member of the class, though certainly a tectonic valley.

The differences between such a rift valley as that of the Red Sea and the Nile valley are obvious. The lower Nile has an irregular sinuous course, and occurs along a broad sheet of marine Cretaceous and Eocene limestones that were deposited in a bay extending south from the Mediterranean. In contrast to these features, the main trough of the

* M. Barthoux has recently shown that some igneous rocks in south-eastern Egypt are of an age contemporary with the older rift-valley movements.

Red Sea is straight, and is quite independent of any former extension of the sea.

Messrs. Hume (1910, p. 387) and Ball (1910, 1911), of the Geological Survey of Egypt, have rejected the view that the Nile is a rift valley, and explain it as a depression due to a downfold. Dr. Ball



The Great Rift Valley: some associated fractions are marked by broken lines

went farther, and claimed the gulf of Suez as also due to folding. Dr. Hume (1910, pp. 387–8), on the contrary, has emphatically reasserted that the gulf of Suez is a rift valley, with folded beds on its floor; and Barron (1907 (2), pp. 180–182) interpreted the gulf of Suez as a rift valley due to faults of different dates. The difference of view may be explained by Dr. Ball's claim for erosion applying only to the post-Miocene history

of the gulf. He remarks (1911, p. 6) that "true faults do occur on both sides, especially in Sinai, and possibly they may exist even in the gulf itself." The gulf of Suez probably originated as a rift valley in the Oligocene, and according to Barron (1907, p. 181) it was refaulted in the Pliocene. The conflict between erosion and faulting relates only to the post-Miocene development; and if the gulf of Suez be the extension of the pre-Miocene rift valley of the Red Sea, it has naturally undergone greater change by denudation than the younger branch up the gulf of Akaba.

Both faulting and folding have contributed to the formation of the gulf of Suez and the Lower Nile. That the gulf of Suez coincides with a line of folding was maintained by Hull (1899, pp. 108–109), who regarded Lower Egypt and Sinai as traversed by a series of north-and-south folds; he explained the gulf of Akaba and the Nile as due to faults acting along downfolds* and the gulf of Suez as due to faulting along an upfold. Whatever may be the origin of the Lower Nile, the balance of evidence, as shown by Dr. Hume, is in favour of the gulf of Suez having originated as a rift valley. It no doubt presents to a smaller extent the features by which the Nile valley differs from the main trough of the Red Sea; nevertheless, though the major cause of subsidence may have been folding on the Lower Nile, it appears to have been faulting in the gulf of Suez.† Most of the original scarps have been destroyed by denudation, and the former north-western continuation of the Suez valley has been sunk beneath the sea, probably by the post-Miocene east-and-west faults along the southern coast of the Levant which dropped Miocene and Upper Eocene beds against the Nummulitic (Lower Eocene) limestones that form the foundation of Cyrenaica (Gregory, 1911, pp. 504–507, etc.).

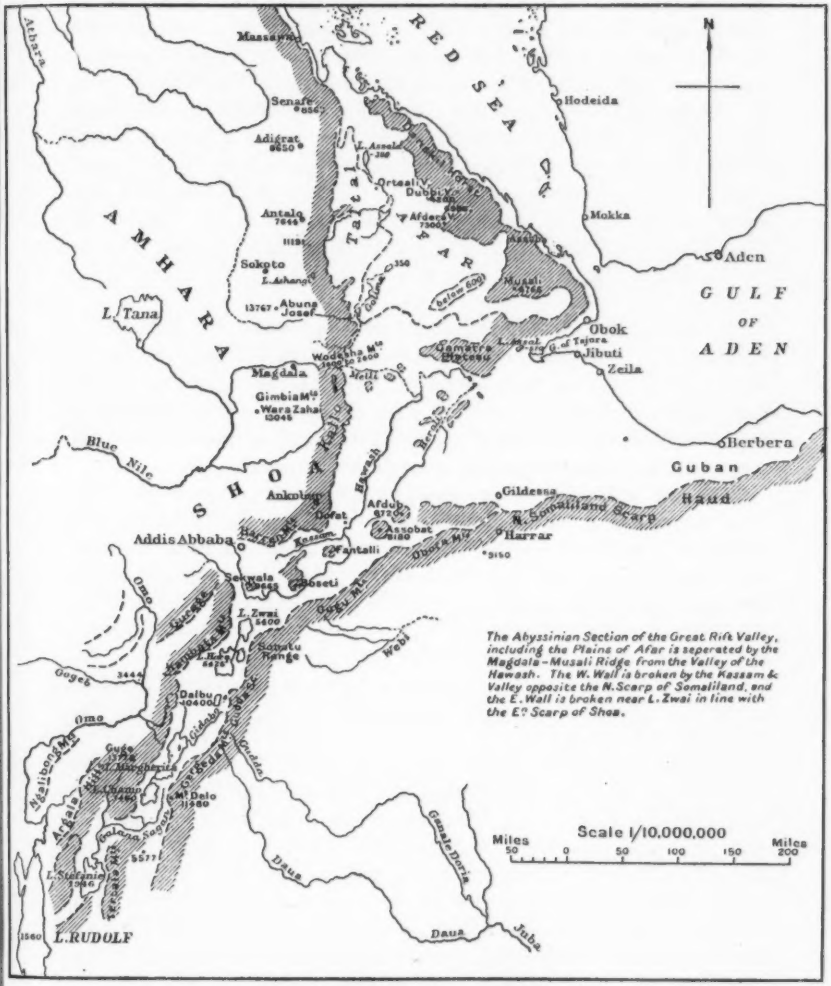
The simplicity of the Red Sea trough is not maintained in the Abyssinian section of the Rift Valley, owing to disturbances due to the transverse faults connected with the formation of the gulf of Aden and the southern coast of Arabia. The Red Sea at its southern end contracts to a narrow outlet through the Straits of Bab-el-Mandeb. The Red Sea trough, on the contrary, maintains its normal width; for its western wall, the face of the Abyssinian plateau, runs southward parallel to the Arabian, and not to the African coast.

Between the Abyssinian plateau and the sea lie the desert plains of Afar and Danakil, which in places sink below sea-level. They are the

* Ball (1910, pp. 71–72), however, represents the gulf of Akaba as having been formed along an upfold.

† Dr. Ball (1910, pp. 75–76) remarks that the hypothesis that the gulf of Suez owes its origin "to trough faulting is unwarranted by geological evidence," and that "the faulting which can be observed along the faces of the boundary scarp of the Nile valley, gulf of Suez, and the eastern wadis is the result of landslips subsequent to the erosion of the hollows." The geological map of Egypt on 1 to 2,000,000 and that on 1 to 1,000,000 sheet 4, both published in 1910, give clear evidence of important trough faulting along the gulf of Suez.

northern entrance to the African portion of the Rift Valley. These plains are separated from the Red Sea by a band of mountainous country, the Danakil horst, which forms the southern part of the Italian



The Great Rift Valley in Abyssinia

colony of Eritrea. To the south the plains of Afar are divided by a ridge from the valley of the Hawash river, which runs southward between the plateaus of Abyssinia and Somaliland, and through an area of once exceptionally vigorous volcanic activity.

In its course through south-eastern Abyssinia, the walls of the Rift Valley are irregular owing to projecting spurs, to breaches cut by rivers, and to smothering piles ejected by volcanoes. The most important of these irregularities occur where the lines that bound the sunkland of the gulf of Aden intersect the Rift Valley. In spite of the interruptions due to these transverse disturbances, the continuity of the Rift valley is maintained from the Red Sea across the basin of the Hawash and along the Abyssinian lake-chains to Lake Rudolf. The walls are usually scarp-like. Their continuity and the trench-like form of the valley are clearly shown on the War Office Map of Abyssinia; (1 : 3,000,000; 1908, General Staff, No. 2319) and the abrupt edge of the plateau and the precipitous nature of the walls are described by many travellers; for example, by Vanutelli and Citerni (1899, p. 239) for the Somaliland side, and by Wickenburg (1903, p. 193) for the Abyssinian side.

Across British East Africa the Rift Valley continues as a comparatively simple trench, with fairly regular walls. The original diagrams by von Höhnel (1891, pl. ii.) representing the walls as continuous have been substantially verified, but the valley gives off occasional bays and bifurcations; its floor rises and falls across a succession of transverse ridges and steps; and the walls vary greatly in height and structure.

The chief exception to the usually straight single course of the valley is at the southern end of Lake Rudolf, where a blind branch on the western side forms the Kerio valley. In consequence the track westward from Lake Baringo (alt. 3190 feet), after climbing the steep face of the Kamasian horst (alt. 8200 feet), descends to the level of 3400 feet at the Ndo River; it then climbs the Elgeyo scarp on the western plateau at 7832 feet. The Kerio valley ends abruptly to the south about 0° 15′ N., though tectonic lines which may represent the continuation of its faults occur in Lumbwa, on the slope down to the Victoria Nyanza from the western edge of the Rift Valley.

The floor of the main valley varies from the level of 1335 feet at the shore of Lake Rudolf, to the windgap just south of Lake Naivasha, where the divide at the head of the Njorowa gorge is at the height of 6400 feet, while the main pass crosses the Longonot saddle at the height of 7000 feet. Thence by successive slopes and steps the floor falls to 2035 feet at Lake Magadi, and to 2060 feet (or 2000 feet according to the German map) at the southern boundary of British East Africa at Lake Natron. The valley is broken by ridges and steps into closed basins, of which the chief, south of Lake Rudolf, are those of Baringo, Elmentaita, Nakuro, Naivasha, the Kedong and Suswa, the basins between Suswa and Lorgasailik, and Lake Magadi. The intervening ridges are made up of volcanic material, and the floor of the valley is studded by volcanoes, some only dormant, others in the last stages of decay.

The walls of the valley vary in character according to differences in

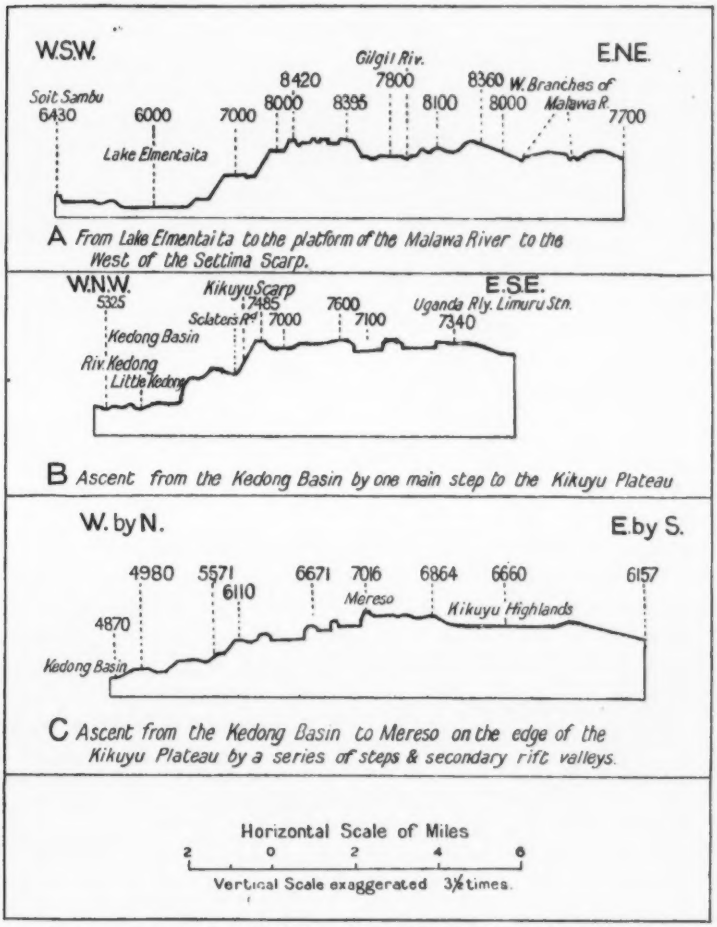
MOUNT KENYA FROM THE HAUSBERG VALLEY ON THE WEST SIDE

THE JUNCTION OF THE MUTONGA WITH THE TANA RIVER

MOUNT LONGONOT

THE CRATER OF LONGONOT

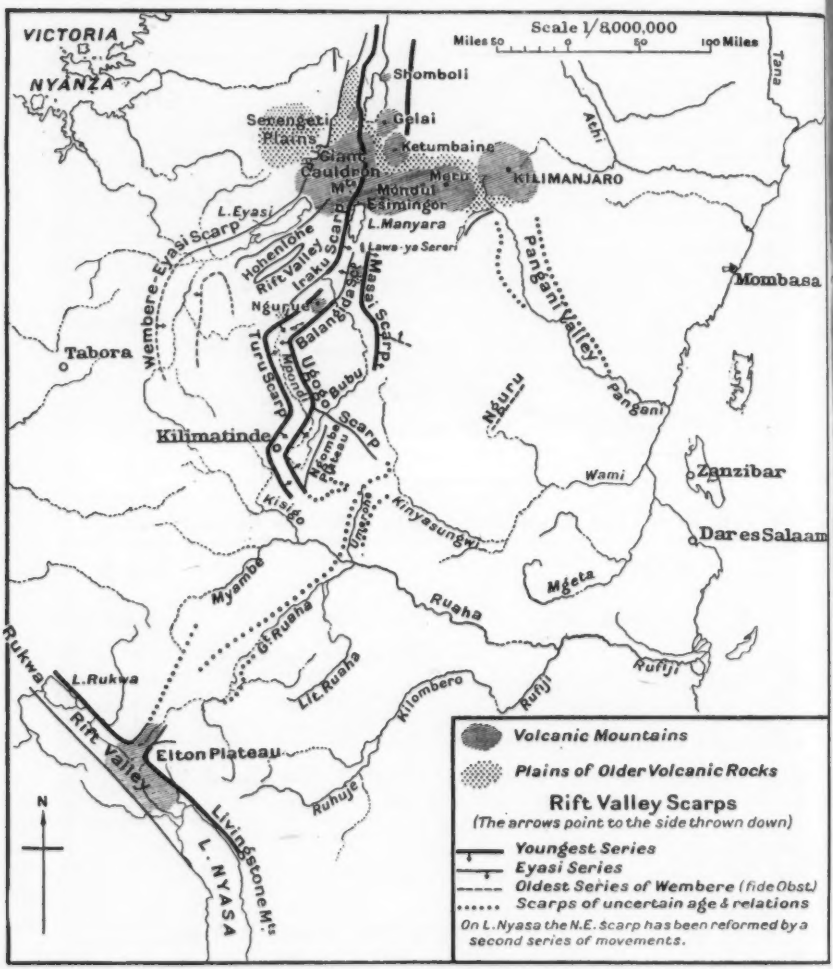
height, and in the geological structure of the adjacent plateaus. The walls are sometimes so abrupt that the trains on the Uganda Railway were formerly run up and down the eastern side on a steep incline by a fixed engine and a cable. There is still no road available for motors down to the floor of the Rift Valley.



Sections across the East Wall of the Great Rift Valley in British East Africa

The chief variations, following the valley from north to south across British East Africa, may be summarized as follows: In places the valley is simple between a pair of trough faults, as near Baringo where both walls are bold scarps, the eastern that of the plateau of Laikipia, and the

western that of the horst of Kamasia. Further south, beside Elmentaita, the plateau along the eastern wall is cleft by many parallel faults, and the difficult ascent to Laikipia crosses a succession of secondary rift valleys.



The Rift Valley across German East Africa

In contrast, the opposite wall offers the easiest ascent from the valley, as it consists mainly of soft volcanic tuffs, that have weathered into gentle slopes up which the railway runs on to the summit of the Mau escarpment.

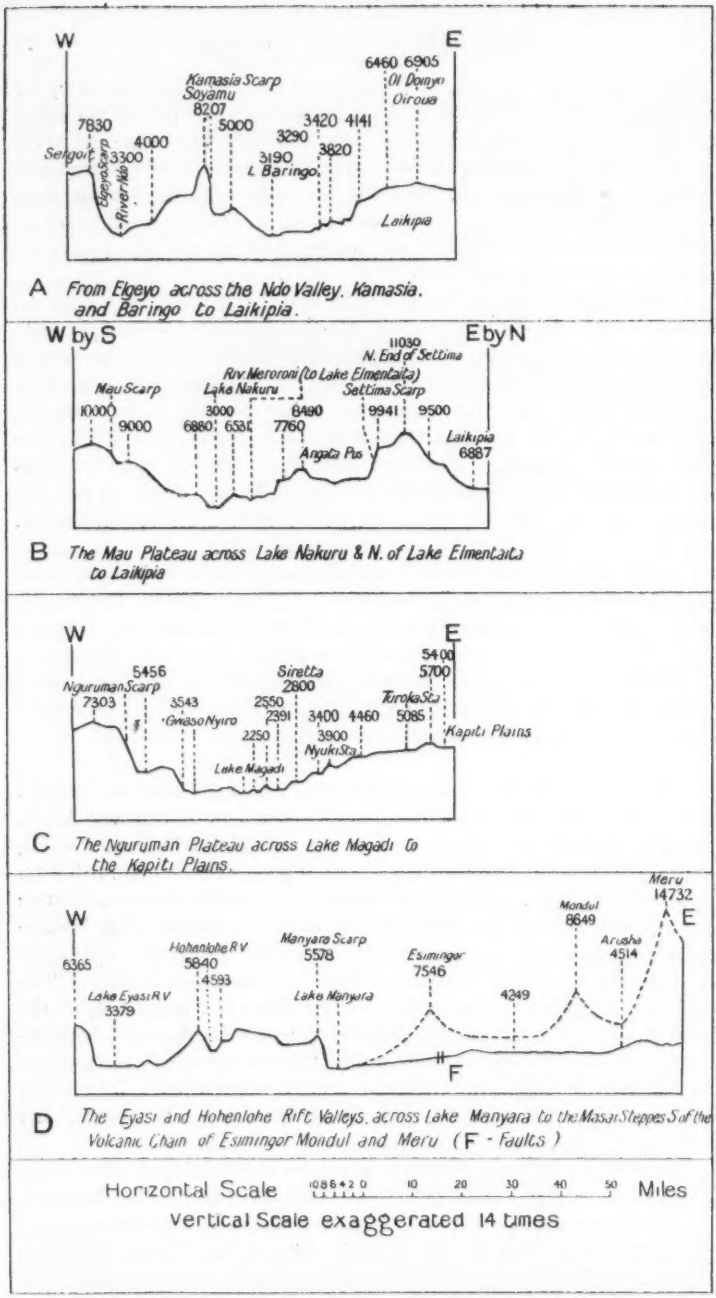
Maufe (1908, pp. 40–42), who confirmed the origin of the valley by faulting, has described some of the faults to which this part of the valley is due. Further south, beside Naivasha, both walls are steep; the lower steps are the smallest, the two main steps are those up a steep scarp on to the plain of Kinangop (alt. 7900 feet), and thence up the Settima scarp on to the eastern plateau. The Settima scarp is in places buttressed by volcanic hills (such as Kipipiri and Isanga), built up around vents on the marginal faults of the Rift Valley.

Still further south, the treads of the steps become narrower until the eastern wall of the Rift Valley above the Kedong basin becomes one wall, broken only near Kejabe by a single narrow platform where the railway descends the escarpment or further south by the smaller shelf used by Sclater's Road. Here the eastern wall is cut back by a deep bay, the Kedong basin, the southern edge of which is a great bastion-like projection of the plateau. This bastion is broken across by a parallel series of meridional faults, between which the blocks are tilted, so that the descent to the Cathedral Peak, the most western and most dissected block, is by a succession of steps with sloping treads.

South of this bastion the wall again becomes simpler and bolder along the eastern face of the Ngong Mountain. Further south the eastern side of the valley is determined by a number of parallel faults; the platforms between them become wider and wider southward, till at Lake Magadi, as shown by Parkinson (1914), the eastern wall consists of long broad steps, which the Magadi railway surmounts without difficulty. The evidence that the valley is due to faulting is conclusive.

After the Rift Valley leaves British East Africa its structure becomes more varied, complex, and asymmetric. In southern British East Africa, at Lake Magadi, the western wall is the precipitous Nguruman scarp, while the eastern wall consists of a series of wide shallow steps, rising on to the Kapiti plains. South of the frontier this change becomes still more marked; to the west is a high plateau, while the eastern steps become lower and lower until they are replaced by a wide sandy plain, which east of Lake Manyara rises eastward without any well-marked steps. The Rift Valley has been replaced by a valley with a fault-scarp only on the western side. The fact that the Rift Valley here is not bounded by fault-scarps on both sides was early recognized; it was remarked among others by Baumann (1894, p. 136); especial stress has been laid on it by Uhlig (1907, p. 487), who called the tectonic feature here a "Bruchstufe," not a "Graben," that is to say a fault-step, not a fault-ditch.

West of the fault-step, however, occur two well-developed rift valleys, of which the larger encloses Lake Eyasi. The floors of these two branches are not continuous with that of the main Rift Valley, as their north-eastern ends have been filled by the volcanic hills of the Winter Highland. These two rift valleys pass to the south-west on a curved course, con-



Sections across the Rift Valley between Lakes Baringo and Manyara

centric to the shore of the Victoria Nyanza, until they end in the plains of Wembere.

Another isolated branch of the Rift Valley system occurs to the south-east, for the valley of the Pangani River is regarded by some authorities (*e.g.* Baumann, 1894, p. 135) as a rift valley. It runs from the southern foot of Kilimanjaro south-eastward to the coast.

The structure of the country across the Great Rift Valley line between 3° 15′ and 3° 30″ S., where it is considered to have only one scarp, is illustrated by Fig. D opposite. The section begins to the west with the rift valley of Lake Eyasi; it crosses the northern end of the parallel rift valley to the east, and descends from the Ngotiek plateau by a steep fault scarp of 2100 feet to Lake Manyara; thence along the main road to Arusha is apparently a fairly gradual ascent to a plateau rising 1600 feet above the level of Lake Manyara. A little north of this line are the western volcanoes of the Meru-Kilimanjaro chain; they include Essimingor, 7550 feet, Mondul, 8550 feet, and Meru, 14,950 feet, and west of the Rift Valley are the volcanic Winter Highlands.

The single-walled structure of the Rift Valley happens therefore where it is crossed by a great east-to-west volcanic chain, and where two branches of the Rift Valley have broken away to the south-west, and one to the south-east. The absence from this section of a sharp eastern wall may be attributed to the block movements to the west and north-east of Lake Manyara, and to loss of lateral support by the formation of the rift valleys to the west and east; hence, instead of the Manyara block having sunk evenly between two faults, it has been tilted, the western edge having sunk along a fault with a downthrow of over 2100 feet; its eastern side subsided either by a succession of faults, each with a small throw, or by the bending of the sinking strip. The former explanation is the more probable, especially as Jaeger (1913, map V.) has observed faults with an appropriate trend just south of Essimingor. The "Bruchstufe" structure of Manyara is merely a further development of the asymmetry of the valley at Lake Magadi.

This arrangement does not continue far; for a little south of Lake Manyara the eastern boundary of the valley south of Lake Lawa-ya-Sereri again becomes more abrupt, and the Sangaiwe Mountains form a steep eastern wall. A well-defined rift valley continues past Lake Balangida to the closed basin of Kilimatinde; but the passage of the Great Rift Valley from this basin onward to Lake Nyasa is obscure.

Between lakes Manyara and Nyasa Suess left a break in the continuity of the Rift Valley of 350 miles, with only the Kilimatinde depression on the line between them. The non-existence of the Rift Valley in this district has been strongly supported by Suess's successor in the chair of geology at Vienna, the late Professor Uhlig; according to him (1907, p. 498), the Great Rift Valley (Graben) is replaced by a fault-step (Bruchstufe), and it is quite different in age, form, and direction from the Ruaha

and Nyasa rift valleys. O. E. Meyer (1912, p. 4) has adopted the same conclusion, and holds that the long tectonic disturbance which begins in Palestine and traverses Eastern Africa, comes to its end in South Ugogo about lat. 6° 35′ south.

There are, however, many indications that the Nyasa Rift is connected with the Great Rift Valley. The gap between them has been steadily reduced. Thus at the southern end Dantz (1900) and Bornhardt (1900, map IV.) represent a well-marked branch of the Rift Valley starting, from north-west of Nyasa, on a north-eastern course towards the Ruaha. Elton's map (1879, after p. 417) represented the Ruaha valley as bounded to the north-west by a series of straight scarps on parallel lines, and to the south-east by what is now known as the Elton plateau.

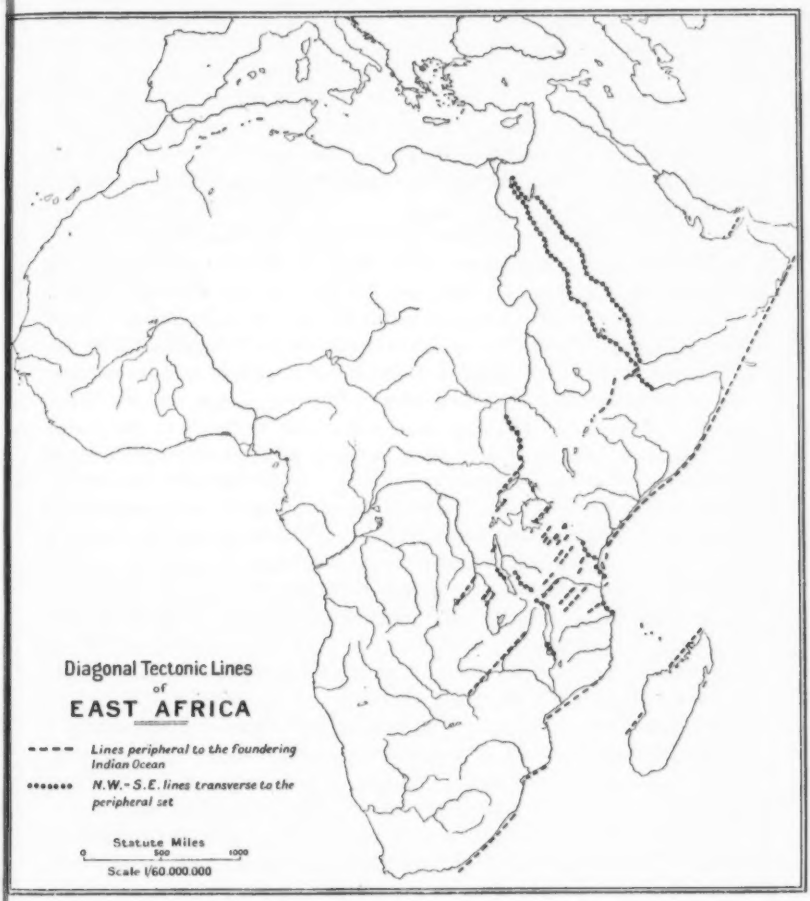
That this valley is tectonic is indicated in the cautious remarks of Stromer von Reichenbach (1896, p. 53), according to whom the Ruaha valley is bounded to the west by a steep, moderately high, sharp-edged plateau (scharfe Plateauland) which has been dissected by numerous rivers; on the eastern side there is no sharp plateau edge, and the valley ends abruptly to the south. Nevertheless the Ruaha valley is called a rift valley by recent authorities, such as Uhlig, Jaeger, and O. E. Meyer. Though the 1/300,000 map, which gives no definite support to this view, would appear to be the most reliable recent authority, its representation of this area is sketchy and incomplete, and perhaps affords less insight into the structure than the impressionist maps of Elton and Dantz.

At the northern end of the gap a definite series of rift valleys has been traced by Jaeger (1913), Obst (1913), and O. E. Meyer (1912). They form a continuous rift valley from Lake Manyara southward to the closed basin to the south-east of Kilimatinde; and Meyer remarks indications that the line bends after Mahaka south-westward past Kumburo Mountain, and Simba Ngulu. No defined rift valley appears, however, on the 1 : 300,000 maps of German East Africa (sheets E_3, E_4, and F_3, and F_4) connecting the Kilimatinde depression and the Ruaha valley. On the western side of the valley a line of scarps is recognizable, but the eastern side is irregular and dissected.

The essential facts established as to the course of the Rift Valley between lakes Manyara and Nyasa are, then, that there is in all probability a continuous tectonic line, and that a rift valley extends for most of the way; but the scarps have been in places obscured by the denudation of the south-eastern wall, or by its burial under volcanic ejecta. The course of the Rift Valley is zigzag, some of the segments trending south-west, and others going to the south or south-east. The one area where the continuity of the Rift Valley is uncertain is therefore between the Kilimatinde and the Great Ruaha basins.

The explanation of the unusual character of the Rift Valley in "German" East Africa is that it is there traversing a belt wherein north-

east to south-west lines are predominant. There are three main series of African depressions, each with a different trend. The oldest series trends east to west, the youngest north and south. Intermediate in age is a series of diagonal tectonic lines, of which the major set trends from north-east to south-west, and the minor set from north-west to south-east.



The major diagonal movements include, on the north-west, the Abyssinian section of the Rift Valley and the Albert Nyanza–Semliki valley. The south-eastern margin of the belt includes the north-western coast of Madagascar, and the sections of the East African coast from Mozambique to Beira, from Cape Corrientes to Delagoa Bay, and that past Durban to

Port Elizabeth, along which the south-eastern corner of the continent has been cut off by post-Cretaceous faulting. The middle part of the belt begins to the north with the south-eastern coast of Arabia and the coast of eastern Somaliland. Inland, it crosses the Rift Valley south of Lake Manyara, and thereabouts it is marked by the rift valleys of the Eyasi district, by that enclosing the Gurui volcano and Lake Balangida, by the rift valley north-east of Kilimatinde, and by the numerous parallel rivers flowing from south-west to north-east into the middle Rufiji basin. The further extension of these north-east to south-west lines forms the great tectonic valley of the Loangwa and middle Zambezi. The evidence as to the ages of these three series of movements is too geological for statement here, but it is necessary to consider their probable sequence, as far as can be judged from the evidence collected by the leading authorities on this region.

The development of the Rift Valley began after the eruption of the widespread plains of lava and tuffs, some of which, according to the descriptions (*e.g.* Jaeger, 1913, pp. 98–100) of the Serengeti plains, strikingly resemble the Kapitian plains of British East Africa. These eruptions were followed by the earth-movements which, probably in the Oligocene, caused the diagonal tectonic lines. Then further volcanic disturbances discharging lavas similar to those of Kenya and the lower parts of Kilimanjaro, piled up the mountainous highlands to the north-north-west of Lake Manyara, and completely filled up the north-eastern continuations of the adjacent rift valleys. Then followed the north-and-south movements while some of the older scarps were renewed by fresh faults, and probably about the same time happened the infall of the elliptical areas which produced the immense volcanic cauldrons of the Giant Cauldron Mountains. The meridional movements have lasted till quite recent times, and volcanic eruptions connected with them still happen at the volcano Doenyo Ngai.

South of the deflecting influence of the Elton plateau the Rift Valley resumes its normal structure, and Lake Nyasa is one of the most typical of the rift valley lakes; it is long, narrow, and approximately straight; though its northern end is deflected to the north-west. Its surface is about 1646 feet above the sea, and it is 2316 feet deep. It lies between high rock walls, which on the north-eastern shore of the lake rise in the Livingstone Mountains, 8000 feet above it. It is continued southward by the valley of the Shiré river, which has all the characteristics of a rift valley until it widens out along the broad basin of the Zambezi.

Before considering its course further southward, let us return to the northern end of Nyasa, and examine the branch which goes north-westward from it. The Nyasa basin is continued by the closed basin of Lake Rukwa, which trends north-westward and breaches the eastern wall of the Tanganyika basin, from which it is separated by a divide at the height of

THE EASTERN WALL OF THE RIFT VALLEY

LOOKING DOWN FROM THE KIKUYU ESCARPMENT TO THE FLOOR OF THE GREAT RIFT VALLEY

A FAULT-PINNACLE NEAR THE SOUTH END OF LAKE NAIVASHA.

DISTANT VIEW OF LAKE ELMENTEITA

about 4000 feet. Tanganyika is the greatest lake on the system, and being 4190 feet deep, is the second deepest lake in the world, and as the surface is at the level of 2536 feet, its floor lies 1664 feet below sea-level. It trends north and south, and lies in a trough which has high walls except where they have been breached at the entrance of intersecting rift valleys, or by a few inflowing rivers. The drainage as a whole is away from the lake, which probably received formerly even fewer rivers than discharge into it at present.

From the northern end of Tanganyika the valley of the Rusisi continues northward and leads to the Nile through one of the most striking sections of the whole rift-valley system. For example, Thruston (1900, 'African Incidents,' pp. 142–3) describes the Albert Nyanza, which lies in this valley, as bounded on the east by a precipitous bank 1000 to 1500 feet high, while "the western shore is formed by a chain of lofty mountains, the highest peaks of which must be at least 8000 feet above the level of the lake. The sides of these mountains are like walls, rising out of the water. . . . The whole scene . . . resembles a fjord in Norway."

The abruptness of the western wall is also emphasized by many other travellers. Thus Stanley (1890, 2, p. 308), who reached its edge from the forests of the Congo, described it as a "yawning abyss," and as made by earth-movements. Colonel Jack (1914, p. 85), who speaks of it as a "big rift," explains (p. 134) that one unexpected result of this abruptness is that, instead of the watershed between the Albert Nyanza and the Congo being sufficiently far back to give us there a valuable tract of land, it is so near the lake as to limit the British territory to "a strip not a mile wide of rough rocky ground falling sheer into the lake."

The floor of the valley is undulating and its walls often uneven. The floor rises from 2536 feet at Tanganyika to 4921 feet at Lake Kivu. The divide across the valley, according to various authorities (*e.g.* Sir Alfred Sharpe, 1913, *Geogr. Journ.*, 41, p. 549) was formerly at the southern end of Lake Kivu, but volcanic disturbances blocked the northern outlet and transferred its drainage to the Tanganyika basin. The height of the watershed between Tanganyika and the Nile is doubtful (Hinks, 1918, p. 225). From this divide the valley declines northward to 3000 feet at the Edward Nyanza, and 2037 feet at the Albert Nyanza.

The major irregularities of the wall appear to be due to two main causes. In some parts the structure has been obscured by the eruptions which built up "the sky-scraping cones," as they were called by Speke, and some of the greatest and most active of African volcanoes. The major cause, however, may be explained by the relations of the valley to the geological structure of the adjacent country. Although small-scaled maps demonstrate the continnity of the valley, more detailed examination shows that the long, straight, even scarps are broken by spurs and gaps, and the valley in places appears to consist of segments arranged in

echelon; some branches are wider than the sections which maintain the continuity of the valley, and with which they overlap.

This feature recurs at intervals from the southern end of Tanganyika to Ruwenzori; for example, the southern end of Tanganyika overlaps the Rukwa rift. South-west of Tanganyika are the two basins of lakes Moeru and Upemba, both of which are described as rift valleys by Belgian geologists (*e.g.* Cornet, 1905, p. 216, and Robert, 1912, p. 8); and the Moeru fractures may explain the breach in the western rim of the Tanganyika basin south of Albertville, and the Upemba fractures may have caused the gap further north, at Baraka. Near that port, the long Ubwari peninsula projects into the lake, and a similar projection from the north-western shore of Lake Kivu is formed by a spur from the western wall. A corresponding spur south of the Edward Nyanza, to the west of the Ruchuru river, forms the western boundary of the pass described by Sharpe. Another gap in the wall is due to the Lake Edward section of the Rift Valley continuing north-eastwards to Lake George, on the eastern side of the great block-mountain of Ruwenzori; while the Semliki river escapes northwards from Lake Edward through a branch valley between Ruwenzori and the mountains south of Beni. Then by a sudden bend the Semliki enters the long Albert Nyanza section of the Rift Valley, while the parallel Edward Nyanza section ends in the highlands of Toru.

This irregularity in the course of the western branch Rift Valley may be explained by its relation to the structural grain of the country. The valley is crescent shaped; it begins along Tanganyika on a course somewhat to the west of north, and bends round till at the Albert Nyanza it runs from south-west to the north-east. In this curve it cuts across the grain of the country; for the average strike of the rocks near Lake Edward * is to the north-north-west, and therefore cuts obliquely across the valley.

A fracture across a plank of grained wood generally gives off overlapping branch cracks or itself here and there alters its course to follow the grain. The overlapping segments and projecting spurs of the Tanganyika–Kivu–Semliki rift is a development of the same feature on a regional scale.

The main continuation of the Albert Nyanza section continues north-westward beyond the Murchison Falls, while by a rift similar in direction to that through which the Semliki discharges from Lake Edward, the White Nile passes northward down a valley, the character of which, as a rift valley, has been shown by Dr. Holmes and Captain Stigand (1916).

The north-eastward continuation of the Albert Nyanza fracture is not yet established. From the scanty information available in 1893, I thought that it probably went eastward, along the line of the Kiogo and Salisbury lake chain, and then by a well-marked pass reached the

* In Karagwe and north-west Ankole, according to Scott-Elliot, 1895, p. 302.

Turkwel, and down its valley to Lake Rudolf. The courses of any connecting fractures between the Albert Nyanza and Lake Rudolf are, however, still uncertain.

South of the Zambezi, the prolongation of the Rift Valley has only been traced in recent years. It has now been discovered by Messrs. Teale and Wilson (1915), that the valley between the Sheringoma plateau and the eastern front of Rhodesia is a rift valley of post-Eocene age. According to their papers the age would be post-Miocene, since the fault is later than the limestone on the summit of Sheringoma plateau. Mr. R. B. Newton, however, allows me to state that after fuller study of the fossils in these limestones he regards the latest of them as of Eocene age.

The main Sheringoma fault is in line with the long meridional section of the coast from Beira to Cape Corrientes. I know of no clear evidence as to the nature of this coast; but from the information available it is probable that the Rift Valley movements along the coast south of Beira coincide with an older line of movements, which there formed either a fault-step with the lower tread covered by the sea, or a great one-sided fold.

Suess regarded this part of the African coast as determined by a great Quathlamba fault; but, as Penck (1908) has shown, there is no conclusive evidence whether the main subsidence along this part of the East African coast was due to faulting or to folding. Penck is disposed to attribute the main influence to a fold; but his own diagrams do not exclude the action of faults, whether primary or accessory to the fold. A monoclinal or one-sided fold is tectonically equivalent to a fault; so it is relatively unimportant whether the coast south of Beira has been determined by fold or fault, so long as it was due to a subsidence of the eastward extension of the land, along a north-and-south line. This subsidence certainly began before Cretaceous times, but it lasted until the date of the Rift Valley movements; and the coast from Sofala to Cape Corrientes appears to be the southernmost effect of the crustal movements of the Great Rift Valley.

Part II.

The Age and History of the Great Rift Valley.

The Great Rift Valley therefore extends from Lebanon to the Sabi river, and its branches reach eastward to the Gulf of Aden, and possibly to the Pangani valley, and westward include Tanganyika and the Upper Nile, and the rift valleys of lakes Moero and Upemba in the Central Congo. This widespread valley system is obviously not the result of some local fracture. Its length is about one-sixth of the circumference of the Earth. It must have had some world-wide cause, the first promising clue to which is the date of its formation.

There are two alternative theories as to the age of the Rift Valley. According to the first, its history is geologically short. This view is

naturally the first to suggest itself on inspection of the valley, as the walls are as fresh and steep as comparatively recent sea cliffs. Such scarps support other considerations in favour of the supposition that the valley is geologically young. Thus the foundering of the Dead Sea might be regarded as within the historic period, as being coincident with the destruction of the cities of Sodom and Gomorrah. Further, the Red Sea basin contains no marine Pliocene beds, while, south of Massaua, Pliocene deposits containing fresh-water shells lie upon its floor. It is moreover obvious that in British East Africa some of the Rift Valley faults are younger than the Miocene lavas, and are therefore not earlier than Pliocene.

That the Rift Valley might not be older than Pliocene or Pleistocene, of course occurred to me in 1893; but the evidence did not seem to justify this conclusion. I was forced to the view that the Rift Valley had a much longer and more complex history. I accordingly suggested a classification (1896, p. 235) of its rocks and earth-movements which attributed some of the associated lavas to the Upper Cretaceous, and some of its faults to the Oligocene. That classification has been regarded as too elaborate, and as attributing too great an age to the Rift Valley.*

The evidence, however, seems to me fully to confirm that classification. For example, it represented, on physiographic evidence, that some of the lake deposits and bedded volcanic tufts in British East Africa are probably of Miocene age, and indicate a great extension of lakes at that period: and this view has been established by Dr. Andrews from specimens obtained by Mr. Hobley and Dr. Oswald.

There is, however, no direct fossil evidence in British East Africa to prove that the formation of the Rift Valley began earlier than the upper Pliocene. But that the Rift Valley of the lower Omo is earlier than that date is established by the fossil mammals (including Dinotherium and Elephant) found there by the Du Bourg de Bozas expedition.

That the Rift Valley is post-Eocene is shown by abundant evidence at various parts of its course, as in Palestine, Egypt, the Red Sea, Abyssinia, Somaliland, and now also south of the Zambezi, by Mr. R. B. Newton's study of Teale and Wilson's collections from Sheringoma. In these places the Rift Valley faults cut through Eocene and sometimes upper Eocene beds. The formation of the Rift Valley therefore began later than the upper Eocene, and earlier than the upper Pliocene. To fix a date within these limits is more difficult, owing to the scantiness of the evidence. There is a much-discussed fossil sea-urchin from Lake Nyasa, which was presented to the British Museum many years ago by an East African missionary. Unluckily, neither his name nor the exact locality was recorded. The evidence therefore is not free from doubt,

* I am glad that Jaeger (1913, pp. 167–8), in his detailed account of the rift valleys of Lake Eyasi district, attributes them to repeated faulting at different and early dates; Obst (1912, pp. 126–7; 1913, pp. 158, 188) adopts the same view.

but it did not seem safe to discard it. Now, thirty years later, the same species of fossil—the *Echinolampas discoidea*, Arch and H., of the Nari beds of Western India—has been found at Lindi, on the coast of German East Africa, and its occurrence as an East African species is confirmed. This Nyasaland sea-urchin indicates that an arm of the Oligocene sea extended up the Zambezi valley into the southern part of the Rift Valley. This conclusion is quite consistent with the evidence from the Red Sea. The work of the Geological Survey of Egypt has shown that the Red Sea trough must have been in existence not later than the Oligocene; the first depression formed a great land valley, which was occupied by a chain of fresh-water lakes that extended from Abyssinia to Palestine. According to Dr. Ball (1912, p. 364), even the main outlines of the present drainage along the Red Sea were established as early as Oligocene times. In the next period, the Miocene, the sea, according to Dr. Hume (1916, p. 21) and Dr. Ball (1912, p. 364), invaded this depression, and deposited what are now the gypsiferous limestones along the coast of south-eastern Egypt. Issel (1900) also claimed that the Red Sea was formed by subsidence, and was in existence in the Miocene (in which he included Oligocene), when it was occupied by a series of lakes. The evidence seems clear that the Red Sea trough was formed by earth-movements at successive dates, beginning not later than the Oligocene and continuing until quite recent times.

The history of the Rift Valley in British East Africa is dependent in the main on the volcanic history of the country; the two are connected, as the subsidence of the earth blocks doubtless forced up the lavas along the fractures. The first stage in the formation of the Rift Valley was the uplift of a long, low arch with the axis trending north and south. The tendency of the Rift Valley to cut across the highest ground is shown on the map illustrating General Smuts' paper in the Society's *Journal* (vol. 51, 1918, opp. p. 192), by the orographic map of British East Africa prepared at the Public Works Department by Mr. Macgregor Ross, and for Nyasa by the Rift Valley passing along the front of the Livingstone Mountains, the loftiest in that district. Suess remarked the upswelling of the Rift Valley borders, and called it their Aufwölbung; and Jaeger (1913, p. 161) refers to the general elevation along the course of the Rift Valley as the "Schwellung" which preceded the faulting.

The second stage was the cracking of the sides of the arch as the lateral pressure was reduced, and the top sank as the keystone of an arch sinks if the end supports give way. The sinking of the keystones of the East African arch into the plastic material below forced some of it up the adjacent cracks, through which it was discharged in volcanic eruptions. Each renewal of the subsidence was followed by renewed eruptions.

To determine the dates of these events, we must consider the relations of East Africa to the Arabian Sea, and therefore go back to the time when

East Africa and India were included in a continent which extended from Brazil to Australia. This continent, Gondwanaland, lasted through the Carboniferous period, and through the two succeeding periods, the Permian and Trias, so that no marine beds belonging to them were deposited on the mainland of tropical or southern Africa. The evidence for the reported marine Triassic beds on the Juba is inadequate; but they occur in Madagascar.

In the next two periods, the Jurassic and Cretaceous, Gondwanaland began to break up, and the sea invaded the coastlands of India and of East Africa. The Jurassic deposits were laid down quietly, undisturbed by volcanic eruptions; but the active earth-movements in Upper Cretaceous times, and the foundering of the floor of the Indian Ocean between East Africa and India, led to volcanic outbreaks on a colossal scale.

These eruptions in western India discharged the lavas (basalts and trachytes) known as the Deccan Traps, which cover about a quarter of a million square miles in western India and perhaps an equal area under the Indian Ocean. The age of the eruptions is fixed as Upper Cretaceous by the shells in the Pab beds of west-central India. As the formation of the Arabian Sea led to such violent volcanic activity in India, eruptions might naturally be expected on the other side of the foundered land; and the widespread plateau lavas beside the Persian Gulf, in southern Arabia, and in Abyssinia have been generally regarded as belonging to the same series as the Deccan Traps.

The volcanic period of British East Africa probably began at the same date, with the discharge of the soda-rich phonolitic lavas of the Kapiti Plains. Mount Jombo, south-west of Mombasa, consists of igneous rocks which are closely related to phonolites, and they are apparently intrusive in the Jurassic beds, and are not earlier than the Cretaceous. They are nepheline-syenites, and were described from specimens collected by Mr. Hobley (Gregory, 1900–2, pp. 223–225). The phonolite of the Kapiti Plains is clearly of considerable geological antiquity, for all the craters through which it was discharged have been swept away, and the floor of the valley which confined the Yatta lava-flows has been left by the removal of its banks as a high plateau.

The subsidence of the Arabian Sea and the outflow of the vast quantities of lava left the East African arch insufficiently supported, and the top of it sank between parallel fractures. This subsidence happened along the first of the Rift Valley faults. That these movements in British East Africa were pre-Miocene is indicated by the evidence from Kikongo, east of the Victoria Nyanza. Some lake-beds in that district have yielded the bones of a primitive elephant *Dinotherium hobleyi*, Andrews. Its age is Miocene, and Dr. Oswald (1914, p. 140) has shown that the lake-beds containing this fossil are earlier than the adjacent Lumbwa phonolites, but younger than the augite-andesite of Kikongo and the volcanic agglomerates of Metamala (Oswald, 1913,

p. 95). If this augite-andesite be of the same age as the older lavas of the Rift Valley, then they also are pre-Miocene, and the phonolites of the Kapiti Plains must be much older than the Miocene. Otherwise, on the hypothesis that the augite-andesite of Kikongo is a very ancient lava which has nothing to do with the modern volcanic series, and that the phonolites of Lumbwa are of the same age as those of the Kapiti plains, the volcanic history of British East Africa would be confined to the post-Miocene, and the oldest of the volcanoes would be Pliocene.

It seems to me incredible that the whole volcanic history of British East Africa can be restricted within so short a time. For instance, Kenya is an old and deeply dissected volcano in a very advanced stage of decay. Its peak appears from a distance as a mere rock pinnacle on the summit of a vast mound. Teleki, impressed by the curved smooth form of the highest valley which he reached, regarded it as the crater; but the crater of Kenya was long since swept away. The mountain was at least 3000 feet higher than it is now, and as it was worn down its crater was obliterated. The central peak of Kenya is the plug of igneous rock (nepheline-syenite and kenyte) which solidified below the floor of the crater and choked the throat of the volcano (Mackinder, 1900, p. 482; and Gregory, 1900, p. 218–9).

The weathering of the volcanic rocks around the plug has produced two different types of scenery: there are rough crags and pinnacles due to ordinary subaerial denudation: there are smooth rounded rock surfaces and blunted summits due to the abrading action of ice, when the glaciers of Kenya flowed down the mountain for several thousand feet below their present level (Gregory, 1894). The glaciated surfaces show that the valleys had been cut down to their present depth by the time of the greater extension of the glaciers. Not only had its eruptions ceased long before the formation of the volcanoes with well-preserved craters, such as the Kibo summit of Kilimanjaro and Longonot, but Kenya had been reduced practically to its present form at the beginning of the Great Ice Age, *i.e.* by the end of the Pliocene. If the volcanic outbreaks of British East Africa began after the Miocene, the whole volcanic history of the country from the first eruption to the wearing down of Kenya into its existing condition would be compressed into only one geological period—the Pliocene.

The fact, then, that the crater of Kenya had been destroyed, and its plug reduced to essentially its present form and dimensions by glacial times, is evidence that Kenya is a very old volcano; and as it is not the earliest of the volcanoes in British East Africa, the volcanic history of the country must be carried back into pre-Pliocene times.

The main stages in the volcanic history of British East Africa seem to be as follows: the oldest lavas are the phonolites of the Kapiti plains and of the Yata plateau, and they were probably discharged in consequence of

the foundering of the Indian Ocean. They may be correlated with the Deccan Traps, and have been begun in the Upper Cretaceous. The eruptions of the soda-rich phonolites culminated in that of the soda-rich kenyte. Then followed a series of eruptions which produced the basaltic agglomerates of northern Kikuyu, vast basalt sheets around Lake Magadi, and the porphyritic basalts of Kijabe and the Settima range. These eruptions were probably synchronous or followed shortly after the first of the Rift Valley faults, and they were succeeded by a long stage of rest and denudation, until renewed volcanic disturbances discharged the rhyolites and trachytes which are especially well developed in the Kikuyu country. Then, after further faulting, ensued a long quiet period, during which the level of the Victoria Nyanza was higher than it is to-day; and the date of this extension is shown by the *Dinotherium hobleyi* bones in the lake deposits to have been Miocene. Then followed the post-Miocene eruptions, including vast plateau eruptions which gave rise to the Lumbwa phonolites and later basalts. Fresh faults enlarged the Rift Valley and led to the building up of great trachyte mountains on its floor, including Suswa, Longonot and Meningai. Some of these latest eruptions must have been quite modern; the lava from the north-eastern part of the crater of Menengai can hardly be more than a couple of centuries old. According to Mr. Hobley, the volcano that he discovered to the west of the Njorowa gorge is so bare of vegetation that it could not have been formed more than a century ago.

The history of some East African lakes also shows that the earlier stages of the volcanic activity in East Africa were passed through a long time ago. Lake Naivasha once stood 150 feet above its present level, and overflowed southward down the Njorowa gorge. The outlet has been cut through a lava-flow which is much older than the great extension of Lake Naivasha, and must be at least Pliocene in date; but that lava-flow is modern compared with the earlier lavas of British East Africa.

The Cause of the Great Rift Valley and its Relation to Contemporary Earth-Movements.

If, then, the plateau eruptions of the Rift Valley area began in the Upper Cretaceous or early Kainozoic, and the main Rift Valley faults happened between the Oligocene and the Pliocene, there are two great regional disturbances in the eastern hemisphere with which they may be correlated—the foundering of the Indian Ocean in the Upper Cretaceous, and the movements which raised the Alpine–Himalayan mountains from the Oligocene to the Pliocene.

These Rift Valley faults run north and south, and end against the Alpine folds as they approach the Taurus Mountains. There are, however, some extensions beyond the Alpine line. The Suez continuation of the Red Sea trough may be connected through the Ægean Sea and the rift valleys of Greece to the sunkland of the Adriatic, and perhaps also to

the contemporary fractures to the north of the Alpine line in western Germany; while the Jordan branch may be connected with the earth-movements around the great Armenian volcano, Nimrud, and the remarkable disruption which broke across the mountains of the Caucasus. Winterfeld has shown (1912), in an instructive memoir, that the north and south fractures of Western Germany began in the Oligocene, and he regards them as belonging to the same system as the African fractures; but his view that the fractures are part of one world-wide system radiating from the North Pole does not accord with their distribution or explain their origin.

The relations of the African movements to those of other continents seem rather as follows: The Mesozoic was an era of long slow deformation of the Earth's crust, including a downward sagging of the North Polar regions and the uplift of the Antarctic. The Equatorial and Temperate zones were buckled by parallel wide and comparatively shallow folds, running east and west. The sections of the African river system trending east and west are probably relics of this corrugation.

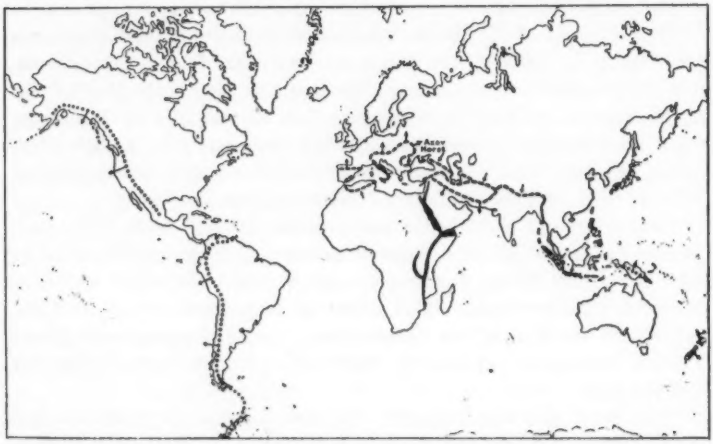
About the end of the Mesozoic era the east and west folds were crossed by north and south lines of elevation. A slow uplift raised an arch along East Africa, forming a range of highlands which extended from Palestine to Natal. This series of movements ended with the collapse of the floor of the Indian Ocean, and the consequent regional volcanic disturbances around the Arabian Sea in the Upper Cretaceous and Eocene.

The next stage was controlled by earth-movements which reached their climax in the Middle Kainozoic. The main earth-movements in the western hemisphere during this era were the north or south advance which buckled the crust into the east-and-west fold-mountains of the Alpine system of Europe (including the Atlas Mountains of North Africa, the Apennines, etc.), and the Himalayan system of Asia.

One remarkable feature of this corrugation of the crust, as has been clearly demonstrated by Suess, is that the European movements were from south to north, and the Asiatic from north to south. This reversal of direction is connected with the essentially different character of the segment of Europe and Africa from that of the segment including Asia and the Indian Ocean. Africa in Cretaceous and Eocene times was a high plateau, either stationary or undergoing further uplift which expelled the seas that ran up the Niger and Lower Nile, and forced back those which spread over the eastern horn of Africa, occupied the Mozambique channel, covered the lowlands of Natal and eastern Cape Colony, and in south-western Africa skirted the plateau of Angola. This process continued in the Eocene, at the end of which Africa was a high plateau only touched by the sea along the Mediterranean, in north-western Africa, near Aden, and on the south-eastern coasts. Coincident with this increased uplift of Africa was the regional subsidence in the Arctic

Ocean, the North Atlantic, and northern Europe. The double movement (subsidence to north and uplift to south) left the foundations of Europe laterally unsupported on the north; and so the crust north of the African mass was pressed northward, buckling the ground in front of it into the fold-mountain chains of Europe and the Atlas.

In the segment of Asia and the Indian Ocean the conditions of crustal stress were reversed from those in Europe. The highland was to the north in Central Asia, while the sinking area was to the south in the Indian Ocean and Indo-Gangetic plain. In Asia, therefore, the loss of


Azov Horst
Eurasian Chains due to movement N. to the W of the Azov Horst, and to movement S. to the E. of it
Circum-Pacific Chains due to pressure towards the Pacific
Great Rift Valley

The Great Rift Valley in relation to the Mountain Chains due to the last chief uplift of Fold-mountains

support and the lateral instability was on the southern side, and Asia was corrugated by a southward movement.

The reversal from the northward European movement to the southward Asiatic movement took place near the sea of Azov, and north of the Black Sea. It is due north of the Rift Valley, which is a rift in the crust along the line separating the segment moving northward from that in which the main stress and movement were southward.

Hence, as previously remarked (p. 27), the geographical features in Eastern Africa are arranged along three main directions—east to west, north to south, and diagonally, north-west to south-east, and north-east to south-west. Of these series the east to west features were caused by the buckling of the Earth's crust in Mesozoic times. The diagonal series are the peripheral fractures formed around the sinking Indian Ocean between the end of the Cretaceous and the Oligocene. The last series, the north and south fractures (sometimes deflected by the resistance of

strong crust blocks or by the readier yielding along the older diagonal folds), were the East African products of the world-wide mountain-forming disturbances which culminated in the Miocene, but lasted from the Oligocene to the Pliocene.

The Contrast between the Great Rift Valley and American Structure.

The structure impressed on the two Americas by the contemporary movements was fundamentally distinct from that of Africa. The American chains of fold-mountains run north and south, not east and west. The dominant influence in America was the subsidence of the Pacific Ocean, which buckled the western edge of the continent into two great north and south chains of fold-mountains; and a corresponding chain may be traced by its broken links along the eastern margin of Asia and Australasia from Japan to New Zealand. There are no meridional fold-mountains in Africa corresponding to those of America and to the western border of the Pacific, nor is there anything in America to correspond with the long tension rent of the Great Rift Valley.

The essentially different character of the contemporary earth-movements of Africa and of the Pacific borders is explained by their antipodal position. Africa was antipodal to the Pacific, and it is in accordance with the well-known antipodal relation of ocean to continent that while the Pacific was sinking and the crust beneath it undergoing compression, its antipodal land should be rising and subject to tension. Africa as a whole, has remained throughout the Kainozoic era as a raised and, judging from its river system, a still rising plateau; but as the crust on both sides sank, it was left unsupported laterally. Instead of its main highland axis being laterally compressed like the coastlands of the Pacific, Africa was in tension, and torn by north and south fractures, along which the sinking of a strip of the crust formed the longest meridional land valley on earth. The Great Rift Valley is therefore due to a long series of earth-movements which began in the Cretaceous, and to faults formed at intervals between the Oligocene and the Pliocene. It owes its unique character to its position antipodal to the Pacific, and its course to the wrench in the crust of the Eastern Hemisphere between the segment pressing northward against Europe and that pressing southward in Asia toward the deepening basin of the Indian Ocean.

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Before the paper the PRESIDENT said: I have the pleasure of calling to-night on Prof. Gregory, professor of geology in the University of Glasgow, who for more than a quarter of a century has taken a special interest in the rift valleys extending right down the heart of Africa, and travelled there for the purpose of studying them. Just recently he has returned from India, where he had been with the Universities Commission, and on his way back again visited East Africa and was afforded special facilities by the Governor to carry out further investigations. He will give us this evening the results of his long study of the great question of the rift valleys of Central Africa.

Prof. Gregory then read the paper printed above, and a discussion followed.

The PRESIDENT (after the paper): We have here this evening General Sir Edward Northey, who commanded the British force which proceeded from Rhodesia into German East Africa, and which he led with such distinguished gallantry, skill, and success. He is now Governor of East Africa. He is home on business, and also, I am sorry to say, because of a serious accident he had out there, and he will, I hope, be good enough to give us a few observations on the remarkably interesting lecture we have just listened to.

Major-General Sir EDWARD NORTHEY: I am afraid that I am not an expert in geology, and I have not prepared a speech, but it may interest you to know that at the beginning of 1916 I was asked to take over the Rhodesian and Nyasaland troops, then on the defensive on the borders of German East, with which four months later I invaded and took the south-western provinces of German East. I then saw a great deal of the country, from the south side, to which Prof. Gregory has so ably referred to-night. Subsequently, a year ago, I was asked to go out to British East Africa as Governor. I have, therefore, seen also the rift valley from the north down to Lake Magadi. You will like to know from quite a casual observer that the rift formation strikes one in a most extraordinary manner, and one almost gets a habit of seeing the difference between what are obviously escarpments formed from subsidence and the ordinary sides of the hills that have been worn away by years of corrosion. There is one interesting point that I think Prof. Gregory may like to hear from me, and that is this. After coming up to the north end of Nyasa when I first went out in 1916, I walked from there to Lake Tanganyika and back, inspecting the troops, and seeing what I could do with them: it then struck me particularly how that rift formation seemed to echelon away from Nyasa to Tanganyika; and, subsequently, when I made my advance and eventually joined hands with General Smuts' troops near a place called Iringa, 200 miles north-east of Lake Nyasa, near the upper waters of the Ruaha river, I made other observations. After we had got over the first 50 miles of mountainous country north of Lake Nyasa, (and there the formation is due to recent volcanic eruptions), we went across a big plain at about 3000 feet, and I have a most distinct recollection that, for about 100 miles, on our left was a great buttress of this cut-away formation which showed that there had been subsidence there. You do not always get the rift where it has sunk on both sides: sometimes you see a distinct break on one side, and you cannot see it on the other side. I am inclined to think that Prof. Gregory, in examining this question as to whether the rift valley goes down to join Lake Nyasa, has been led astray by the fact that for 50 miles north of Lake Nyasa the rift is broken by volcanic formation, and this is more interesting now for the following reason. The first large town, if you can call it so, which we came to was the southern capital of German East Africa, a place called Neu Langenburg, 40 miles north of Nyasa; just north of it, standing about 10,000

feet above the sea, was a large extinct crater called Rungwe, which must not be mixed up with Lake Rukwa to the north-west: I took a lot of trouble to find out what was known of this volcano, and there were old natives who said that their parents had remembered smoke coming out. Since I was there that volcano has broken out again, and the whole town has been levelled to the ground. What I wish to point out is that I think the rift formation does go north-west from Nyasa, but is lost sight of because of the break in it caused by volcanic eruption. It was the very greatest pleasure to me to welcome and assist Prof. Gregory in his work in Africa. He used to make little trips and come and tell me about them; and everything he tells one is of most extraordinary interest, and he has a pithy way of explaining and putting his points. Having seen these formations, I can assure you that the slides put on to-night give you a very true idea of how they appear.

Mr. C. W. HOBLEY: I have been greatly interested in the paper Prof. Gregory has given us this evening, and for two reasons: first of all because I have been associated with East Africa for many years and have taken a small part in the exploration of that country, and, further, during my service there have taken a great interest in its geology, and endeavoured to obtain a general insight into the structure of the country; secondly, because of my long friendship with Prof. Gregory. I first met him about 1892, and the occasion was this: he returned to Mombasa very disheartened from the break-up of an expedition with which he had great hopes of doing good work; a projected expedition up the Tana which broke up for reasons I need not enumerate. Prof. Gregory returned to Mombasa with his adventurous spirit undaunted, and he decided to endeavour to make an expedition to Kenya and the highland region at his own cost. He appealed to the officials of the Imperial British East Africa Company for assistance, and I had the honour to help him in fitting out a caravan. I gave him the best headman I could procure, about thirty porters, and my blessing, and then awaited with anxiety for his return. For many months he disappeared and we almost gave him up. On several occasions we heard rumours that the Masai had cut him up, but could not send to inquire. The interior at that time was not nearly so safe as it is to-day, and the marvel is that he attained as much as he did on this trip. However, one day he turned up, quite cheerful but looking ill and worn. He had come through after many adventures, and the results of that trip are known to most of you from the account of them published in a book now historical: 'The Great Rift Valley.' The title of that book gave the name to the valley. Twenty-five years later I had the pleasure of being associated with an expedition which Prof. Gregory made in East Africa, the one to which His Excellency Sir Edward Northey has referred, and on this occasion I had the good fortune to accompany him. He has not given us any particulars of his journey, and I am sure if he had done so it is unlikely that he would have told you of the very narrow escape he had from a bad-tempered rhino. Prof. Gregory's latest visit to East Africa was arranged in order that he might give the Government of British East Africa some advice on certain projected borings for water. This tour has however enabled him to check the theories he had built up with regard to the structure of the country as long ago as 1893. The full and detailed exposition of these views will be of great value to the scientific world, and particularly to the projected geological survey of the country, because they will form a firm basis on which that survey can build. Local workers in Africa up to now have been to a great extent rather like the man who could not see the wood for the trees—they become engrossed in the local aspect of the problems, but when a man with world-

wide experience like Prof. Gregory comes along he reduces the whole problem to proper perspective. I hope that Prof. Gregory will a little later on be able to revisit East Africa and spend several months there, and eventually publish a *magnum opus* which will be a standard work on the tectonic structure of the country. With regard to the technical matter of the lecture, I must say that the age of these great phonolite beds which spread over such a large area in East Africa is a problem which has afforded many of us great thought. Personally I never believed that they were of such great age until I had the pleasure of travelling with Prof. Gregory and hearing his arguments in detail. There is on the eastern side of the Athi river a very big ridge called the Yatta plateau. This is very narrow, but stretches for a distance of about 200 miles parallel with the river. Prof. Gregory's theory is, I believe, that this is the relic of an extension of the great lava-sheet, but preserved because it lay in the valley of an old river. I regret that he had not time to visit it, for this is one of the geological problems which needs further consideration, and I hope that on his next visit he will be able to give it more detailed attention. The geological problems of British East Africa are various and vast, but they have got to the stage when they can only be solved by detailed survey and the help of a big-scale accurate map. The day when the geographer walked through the country and made compass sketches is past. We are now getting down to accurate surveys of small areas, and detailed geological surveys, whether for economic or theoretical purposes, depend on surveys with accurate and large-scale maps. With regard to the title of the paper, I think this is one of the few instances in which a scientific man has given a name to any part of the world which has obtained popular vogue. The Great Rift Valley's name was Prof. Gregory's invention, and every week one sees in the local papers notices of Rift Valley Hotels and sales of Rift Valley farms, and such like.

Mr. W. McGregor Ross: I am not a geologist, but a civil engineer, and I should like to speak for a moment upon the application of these problems, which Prof. Gregory has done so much to solve, to the industrial conditions prevailing to-day. One of the effects of having a region seamed by these deep vertical cracks or faults is that surface water-supplies, which would otherwise be available, go below and are lost underground, and one of the main reasons why the Government of East Africa invited Prof. Gregory to visit the country on this occasion was that he might advise as to the possibility, or likelihood, of our being able to recover some of the underground supplies of water which are probably there, due to the passing of surface supplies downwards. The result of his advice may, we hope, be that steps will be taken to recover something of those supplies in specified districts, and the economic effect of that upon the East Africa Protectorate, and not only there but upon human conditions elsewhere, may be very considerable indeed. The portion of the Rift Valley which Prof. Gregory visited on this occasion is occupied in parts by farms under white ownership, and in other parts by native tribes, who are ranchers on a tribal scale. The principal tribe there is the wealthiest nation on the face of the Earth at the present time—not excluding some profiteers we know of. They are about 25,000 in number, and they are said to be worth £300 sterling a head,—man, woman and child. Their stock of cattle runs to upwards of a million head, and sheep and goats several millions, and if water were obtainable in considerable stretches of the territory which Prof. Gregory has alluded to, a very large increase in the stockage of that country would be possible, which is at present impossible owing to the dry weather which we have annually. The effect, then, of turning the insight of geologists

into technical advice on obtaining underground water, will be a very large increase in the stockbearing value of an enormous piece of British territory, and secondly, in a really almost overwhelming invitation to cold-storage concerns to start operations in the Protectorate, and invest capital in their operations among the rancher community. This, we may hope, would lead to the necessity of converting the Uganda Railway from a single to double line, at least for a portion of its length, and this again would employ further British engineers and set rolling mills here at work, with other industrial developments too numerous to follow up. Therefore these really intricate problems of geology on which Prof. Gregory has touched to-night have this extremely practical side, that the advice which he is in a unique position to give upon the structure of this particular territory may be of extreme value to the local Government in expediting and advancing the development of the country.

The Very Rev. Sir GEORGE ADAM SMITH: I am here only by chance and did not expect to speak, but having been called upon I cannot fail to pay my tribute to the lecture we have heard to-night. Prof. Gregory has quoted me with regard to the beginning of this great rift in the world's surface, and as having said that there is nothing like it on Earth but that there may be something like it upon another planet. It seemed to me, as I heard him to-night, as if he were taking me into that other planet, from the little region of Palestine into the great continent of Africa, and the practical conclusion that has been forced upon me is that we want him to come to Palestine and do some work there, as he has done in the continent of Africa, on the continuation of the great Rift Valley. In the first place, we have never had studies of the geology of the whole land which have thoroughly exhausted the subject, in spite of all that Hull and his English successors, and the German Blanckenhorn and the French Lartet and Diener have done in that little bit of the world. We need another geological survey of the whole land, and no one could do it better than Prof. Gregory. The last speaker's remarks lead me further to say this, that in addition to a scientific geological survey of the whole land, we need the practical application of its results in the recovery of the fertility of that country to the extent which it reached both in Old Testament times and, as I believe and indeed as we all know, in the early Arabic Moslem period. It is just this matter of discovering underground water for irrigation which is going not only to restore Palestine to its former productiveness but to one beyond anything it knew even in the most flourishing former period of its history. I know the deserts which separate the main part of the United States of America from California, and how they have been transformed on the Californian side into some of the most productive parts of the Earth's surface. I believe the same can be done with the southern part of Palestine where the ruins of Byzantine cities are still strewn across the sands—proofs of the former fertility of that region; and it is just such an expert as Prof. Gregory that is needed out there to start the same restoration of Palestine as of the desert surrounding California. The only other remark I have to make is a very obvious one, and it is that we are more and more coming to see that prior to any intelligent study or mastery of the subject of history lies a knowledge of the physical basis on which all history rests and is moved. Until you understand the lie and the lift of the Earth's surface you cannot understand either the political, or the military, or the economic movements of history.

The PRESIDENT: If there is no one else who would like to take part in the discussion it falls to me now to propose a very hearty vote of thanks to Prof. Gregory. He has given us a wonderfully interesting and very lucid description

of the origin of this unique feature in the Earth's surface. To us travellers who have been about the world it is extraordinarily fascinating to hear a geologist, a great master of his subject, telling us in clear and simple language, how the features of the Earth's surface, amongst which we travel, have originated. I have had the great pleasure of listening to the Director of the Geological Survey in India describing how the Himalayas have arisen, but I have never listened before to any one describing a great depression such as these great rift valleys of Africa. During the first part of the lecture I was listening anxiously to hear the actual cause of this great subsidence. "Faults" are talked about by geologists, but one does not realize quite clearly what has been the cause of a fault—how it is that a certain part of the Earth's surface has sunk away leaving other parts of the arch still standing. That was very clearly explained to us by Prof. Gregory. And we listened with the greatest interest to his description of the origin of those wonderful depressions on the Earth's surface which run down from the Dead Sea to the southern part of Africa. We would also like to hear something about the age, but here geologists are extremely cautious. They talk about the age of London Clay, about the Miocene period or Pliocene period, but they never come down to actual figures. They talk about recent times. I remember Mr. Hayden of the Indian Geological Survey telling me that the Himalayas were a quite recent formation, but by "recent" he meant near about three million years old. I gather the rift valleys are also what the geologists call "recent." What we liked in Prof. Gregory's lecture was the feeling that he was dealing with a subject from a big point of view. He was taking the Earth in his hands, as it were, and looking at it all round underneath and inside, as well as on the top. I have not before realized the relation there was between one side and the antipodes, but one understands now how the depression, the foundering of the Pacific Ocean, has had something to do with the features of the land in the centre of Africa. One of the speakers has referred to the difficulty of seeing the wood for the trees, and remarked how men engaged on the spot merely see their little problems and how these engage their attention, yet what a pleasure it is when some one, taking a general view, comes and points out the relation of what they see close at hand to the great general problem! I have often felt that when I have been in out-of-the-way parts and had with me these men who take a general view. I am sure we have experienced that great pleasure also to-night. I will ask you, therefore, to give to Prof. Gregory a most hearty vote of thanks for his exceedingly interesting and very lucid lecture.

Major L. F. I. Athill sends the following note as an addition to the discussion:

On the south-eastern shores of Lake Rudolf lives a small fish-eating tribe called the Elmolo, now reduced to the verge of extinction by raids. Its old men relate that many years ago the Elmolo were a large tribe, rich in flocks, and ranging over the area, then dry land, which is now covered by the southern waters of the lake. One day, when the ancestors of the existing remnant were herding their goats near the foot of Mount Kulah, there was a terrible earthquake, and the ground where their fellow-tribesmen were pasturing gave way, the waters of the lake rushing in from the north and filling the depression.

An island, now known as Elmolo or South Island, escaped submergence, and from it the smoke of fires continued to rise for some thirty years, after which period it was no longer seen. The Elmolo conjecture that during that time some survivors of the catastrophe were keeping themselves alive on the

island by catching the fish which abound in the lake and which form their own staple diet. The manner in which the tale is told suggests that the events took place only a few generations back, but the Elmolo are incapable of estimating time beyond the limit of their own experience. To this day Elmolo Island remains unexplored, and when it is at last visited it will be of great interest to learn whether any traces of former human habitation exist.

Count Teleki reported that the volcano at the south end of the lake was emitting clouds of yellowish smoke in 1888. This volcano seems to have been extinct for the last eight years at least, but another story told by the Elmolo bears witness to its recent activity. They say that the crater is the home of a witch-doctor, and that within very recent years they have seen the clouds of dust raised by his cattle, and have heard them lowing as he drives them to his kraal at sunset.

The Elmolo are markedly more intelligent than their meat-eating neighbours. Is this an argument in support of the brain-making properties of a fish diet?

A BRIEF REVIEW OF THE EVIDENCE UPON WHICH THE THEORY OF ISOSTASY HAS BEEN BASED

Colonel Sir Sidney Burrard, K.C.S.I.

Read at the Afternoon Meeting of the Society, 12 *April* 1920.

IN putting forward the theory of Isostasy geodesists take upon themselves a considerable responsibility. Geodetic methods are technical, and they are described in technical language, which has not been studied by laymen. Geodesists have therefore to weigh their words well before they commit themselves to the statement that the evidence in favour of Isostasy is incontrovertible. The Royal Geographical Society has invited me this afternoon to summarize briefly the evidence in favour of Isostasy.

The theory of Isostasy ascribes to the Earth's crust a peculiar structure; it states that all mountains and heights standing above sea-level are compensated by deficiencies of matter underlying them below sea-level, and that all oceans and surface hollows dipping below sea-level are compensated by excesses of matter underlying them in the crust.

The theory that deserves our confidence is the theory that best fits the observed facts. The force of gravity has been observed in different parts of the Earth, and the crucial question is this: Does the theory of Isostasy accord with the observed facts?

I will illustrate my meaning by borrowing an example from the tides. There are two methods of predicting the height of tidal high water. For the tides in the Red Sea the first method of prediction gave heights differing from the actual observed heights of the tide by amounts varying from 9 to 16 inches, whereas the second method predicted heights that agreed with the observed heights within 2 to 4 inches. Which of these two

methods of prediction deserves most confidence? One instinctively feels that if a man can foretell what is *going to happen*, his methods deserve our confidence. I wish now to apply a similar test to Isostasy.

The force of gravity has never yet been observed at the summit of Ben Nevis. Supposing that we now take a pendulum to Ben Nevis and observe its swings. Before we set out, three different prophets belonging to different schools will come to us, and each will say, "Let me predict the force of gravity at Ben Nevis before you observe it, and then you can test my powers as a prophet." The first prophet will be the follower of Bouguer, the French geodesist who observed in Peru. He is a believer in the strength and rigidity of the Earth's crust. His arguments are as follows: Ben Nevis is composed of solid rock, its foundations are solid, the crust has easily supported its weight for millions of years. Therefore as an honest man I base my calculations on observed facts, and I must assume that Ben Nevis is a solid and extra mass supported by the crust.

The second prophet is the follower of Helmert. He argues as follows: Ben Nevis may appear solid to geologists, but whenever we measure gravity in the Alps, the Rockies, or the Himalayas, our results show that mountains are not so solid as they look. In order therefore to predict gravity at Ben Nevis, I think it is prudent to assume that Ben Nevis is made of air, and that Ben Nevis will behave as if it were an empty egg-shell (see International Geodetic Reports, 1900–1913).

The third prophet is the Isostasist: he is the follower of Hayford. He does not agree with Bouguer that Ben Nevis is an extra weight upon the crust, or that the Earth's crust is strong: he regards it as a yielding structure. But he does not agree with Helmert that Ben Nevis is made of air. He argues that the extra mass of Ben Nevis is compensated by a corresponding deficiency of mass existing at a *great* depth in the crust.

Let me pause for one moment to point out the essential difference between the second and third prophets. They both assume that the extra mass of Ben Nevis is wholly compensated: in this they agree. But they differ in the depth of this compensation. Helmert assumes the compensation to occur at sea-level; Hayford assumes it to occur at great depth. Now if the deficiency of mass which constitutes the compensation occurs at sea-level, its effects on a pendulum immediately above it will be far greater than if the compensation is buried at depth. On the other hand, a compensation that is buried at great depth under Ben Nevis will affect the pendulums not only at Ben Nevis but at all surrounding stations, whereas Helmert's compensation at sea-level will only affect Ben Nevis itself and will have no lateral effects.

Much evidence has now been accumulated from all parts of the world in favour of Hayford's theory of Isostasy. Ben Nevis will be found to be compensated, and its compensation will be found to be deep. The third prophet who bases his predictions upon these ideas will give you an accurate figure for the force of gravity at Ben Nevis; I feel quite con-

vinced that his prediction will be found to agree with the actual result when the latter comes to be observed.

By way of example, I will first take five typical geodetic results which have been obtained from mountains in America ('Investigations of Gravity and Isostasy,' William Bowie, 1917, p. 59). The figures represent the discrepancies between the predicted and the actual measurements of gravity. I need not raise now the question of the unit employed, for we have only to consider here the *relative* magnitudes of the discrepancies. You will see that Bouguer's predictions are always too large: the negative sign denotes that the strength of gravity as predicted has proved too large when compared with the actual value observed.

Bouguer's mountain results are always bad; and if his method is used to predict for Ben Nevis, his prediction will prove much too large.

TABLE OF PENDULUM RESULTS.

Station.	Height in feet.	Gravity Anomaly. Bouguer.	Helmert.	Hayford.
America *—				
Arizona	7,187	−162	+ 43	+ 9
Pike's Peak	14,159	−214	+ 216	+ 29
Wyoming	7,873	−208	+ 44	+ 6
Gallup	6,565	−211	+ 9	− 5
California	3,458	−103	+ 13	− 2
Asia †—				
Mussooree	6,924	−123	+ 84	+ 53
Sandakphu	11,766	−155	+ 189	+ 48
Quetta	5,520	−153	+ 31	+ 7
Ootacamund	7,395	− 46	+ 195	+ 12
More (Tibet)	15,427	−419	+ 100	+ 18
Europe *—				
Stilfersjoch (Austria)	9,108	−141	+ 142	− 18
Schneekoppe (Germany) ...	5,296	− 26	+ 139	+ 21
Gornergrat (Switzerland) ...	9,952	− 92	+ 218	+ 45
St. Bernard (Switzerland) ...	8,260	−113	+ 141	+ 2
Franzenhohe (Austria) ...	7,220	−182	+ 73	− 22

Now the table of results shows that Helmert's method of compensation at sea-level gets rid of the negative discrepancies of Bouguer. But Helmert goes too far the other way: he replaces the Bouguer negatives by a series of objectionable positive anomalies. This is because he assumes the compensation of a mountain to be all near the surface. Hayford's assumption of compensation at depth will be seen to be very successful. The negative values showed that Bouguer gives too great a mass to mountains: The positive values showed that Helmert's compensation was excessive, so Hayford removed Helmert's compensation from sea-level and buried it at depth, and then his results agreed closely with actual observations.

Now we will turn to Asia. Hayford based his theory entirely on results observed in America. Yet when we applied his theory to India, we found the same remarkable improvement in our results as he had done.

* 'Investigations of Gravity and Isostasy,' by Wm. Bowie. 1917.
† Professional Paper, Survey of India, No. 15, by H. Couchman.

I give you five typical mountain results from Asia: two in the Himalayas, one in Tibet, one in Afghanistan, and one in South India. The school of Bouguer has given us predictions for the mountains of Asia that are always too large. If you had taken a pendulum to these Indian mountains, and if before you set out Bouguer had given you these figures, foretelling your results, you would have thought him a poor prophet.

Now comes Helmert to Asia. He attempts to get rid of Bouguer's big negative anomalies by applying complete compensation at sea-level. Just as occurred in America, his method creates large positive anomalies in Asia. Hayford then lowers the compensation from sea-level to a great depth in the crust, and a diminution in the errors at once ensues.

Now we will turn to Europe. We started with a theory propounded in America; we tested it in Asia and found that it held good; let us now test it in Europe. I have included in the table five more typical mountain results: two from Austria, two from Switzerland, one from Germany.*

All the Bouguer results are negative: Bouguer attributed to the mountains of Europe a greater mass than they possess. All the Helmert results are positive: by introducing complete compensation at sea-level Helmert has given to the compensation too large an effect. Hayford's results are in the last column: they show that the large Helmert anomalies can be eliminated by lowering the compensation from sea-level to great depth. They show that this same theory of Isostasy, which has so closely agreed with observed facts in America and Asia, explains the structure of the mountains of Europe also.

I have left the station of More in Tibet to the last. This is the highest pendulum station in the world. Its observed result has been discussed for fifty years. Bouguer's theory gave to More an immense negative anomaly; Helmert's theory got rid of this big negative anomaly, but replaced it by a positive anomaly. Major Cowie has recently calculated the Hayford value for the Tibetan station of More; his result is most striking. The great anomaly in Tibet which has been puzzling geodesists for years can be explained by Hayford's theory of Isostasy. It was a long time before I became a complete convert to Hayford's theory, but nothing influenced me more than this More result. The theory of Isostasy not only explained the gravity anomalies of America, Asia and Europe, but when applied to the highest pendulum station in the world it gave a result that differed by only 18 units from the actual result observed.

I have so far been dealing with the strength of gravity only, but the local peculiarities of gravity and its variations from place to place can be observed in two independent ways. Firstly we can observe the strength of gravity with a pendulum, and we can note how that strength differs

* I am indebted for these results to the calculations by Bowie in his 'Investigations of Gravity and Isostasy.' 1917.

from the normal. Secondly we can observe with a plumb-line the exact *direction* of gravity, that is its local deviation from the normal vertical. By means of the plumb-line we can determine how the direction of gravity on mountains deviates from the normal direction deduced from theory. In all continents the plumb-line has given independent confirmation of Hayford's theory. The plumb-line has everywhere confirmed the pendulum. I will not trouble you with actual plumb-line figures, they are to be found in the international reports. I will sum them up by saying, firstly, that they condemn Bouguer's theory of a rigid crust, and secondly, that they support Hayford's hypothesis of a deep compensation in contradistinction to Helmert's hypothesis of a surface compensation.

In comparing Helmert's compensation with Hayford's I have more than once remarked that Hayford lowered the compensation from sea-level to a great depth. This statement is a generalization: what Hayford did exactly was to assume that compensation was distributed uniformly downwards from sea-level, and he found the depth of such an assumed compensation to be 70 miles. He assumed uniform distribution in depth in order to facilitate computations.

The attraction at the surface of this uniform distribution (down to 70 miles) is nearly the same as the attraction of a compensation which is all concentrated at 25 miles deep.

From geological considerations Professor Chamberlin reached the conclusion that isostatic compensation would not be uniform but would decrease gradually with depth. Hayford has shown that Chamberlin's hypothesis of a compensation decreasing gradually to a depth of 193 miles was just as much in accord with geodetic results as his own hypothesis of uniform distribution. The two hypotheses agree in their results, because from the point of view of mathematical attraction the effective depths of compensation are the same in both cases. In the case of Hayford's uniform distribution to a depth of 70 miles, the effect is approximately the same as a compensation concentrated at a depth of 25 miles, and in the case of Chamberlin's distribution decreasing to 193 miles, the effect also approximates to that of a concentration at 25 miles. Therefore all we can say to geologists is that any distribution of compensation may be adopted, provided that its resultant depth is 25 miles. For example, a compensation that is nil at sea-level, and which gradually increases to a maximum at 25 miles, and which thereafter gradually decreases to nil again at 70 miles will have a resultant depth of 25 miles, and will be found to suit the observed geodetic results.

Geodesy has produced much evidence in favour of the view that the condition of Isostasy exists throughout the Earth's crust, but it has produced no evidence of the process by which isostatic readjustments are constantly taking place in the crust. The process is not a matter of evidence, it is a question for the opinion of physicists. Let us compare the land and sea surfaces. Under the influence of gravitation the surface

of the ocean is a level surface, but it is continually being disturbed by atmospheric forces and becomes deformed into waves and hollows; the force of gravitation is able to remove these waves and hollows and to restore the level surface.

The surface of the land is also being deformed by forces, but owing to the rigidity of rock the force of gravitation is unable to restore the level of the land surface. Though the land surface remains deformed, the condition of Isostasy supervenes and the distribution of mass in the crust becomes similar to what it would be if the crust were a fluid under the influence of gravitation. Geodesy teaches that in a region where an extra load of rock is accumulated, the underlying crust decreases in density—and wherever rock is removed or eroded, the crust underneath increases in density. I therefore conclude that the condition of Isostasy is brought about by the force of gravitation acting upon a crust the structure of which is not understood.

APPENDIX

The Bouguer formula is $dg = +\frac{2gH}{R}\left(1 - \frac{3\delta}{4\Delta}\right)$, where dg is the correction to observed gravity, g is gravity at sea-level, H is elevation above sea-level, R is the Earth's radius, δ is density of matter above sea-level, Δ is mean density of the Earth. The first term takes account of elevation, the second term takes account of the attraction of the local mountain mass.

Helmert's formula is $dg = +\frac{2gH}{R}$, the second term of Bouguer being omitted.

Hayford divides the whole surface of the Earth into compartments, and for each compartment he deduces by the aid of maps a correction for both topography and isostasy; the sum of all these corrections he then adds to Helmert's formula $dg = +\frac{2gH}{R}$.

Before the paper the PRESIDENT said: It is a great pleasure to us to have here this evening Sir Sidney Burrard, who was Surveyor-General of India, and who has devoted many years' study to this subject of isostasy. It is rather difficult for us simple geographers to understand, but he is putting it forward before us this evening with great clearness, so that I think even the meanest intellect will be able to appreciate its meaning.

Sir Sidney Burrard then read the paper printed above, and a discussion followed.

Colonel H. G. LYONS: I have never had the occasion to discuss observations with respect to Hayford's theory of isostasy, for in Egypt the opportunity did not occur; and so I have not had that practical acquaintance with the problems that one would have gained by making investigation on observations in one's own area of survey. But the theory itself has always seemed to me to be one that is well and reasonably based, even though additions and modifications may come in the future. We have seen that it meets the observational requirements well in

three regions of the Earth, and I should like to ask Sir Sidney Burrard whether the Italian surveys have been able to find similar results, or whether perhaps their gravity determinations are not complete enough; also whether the Austrians, who have done a considerable amount of geodetic work, have been able to add useful information on the same lines in the more eastern part—in the Hungarian region, besides the portion of the Alps that has been already referred to. There will be, one may reasonably suppose, a certain lack in the isostatic compensation adjusting itself in areas where large crustal movements are recent and perhaps even still in operation. Such an area as the margin of the Tibetan plateau would, I imagine, be a typical region. Hayford considers the condition of the crust over the American area as being defective in rigidity and therefore having taken up the isostatic compensation. Is there any indication in some parts of the Central European area, where the old rocks are particularly developed, that defect of high rigidity occurs in that region? I am sure that Sir Sidney Burrard is quite correct in saying that it is for those physicists who are particularly interested in the crusts and the internal part of the Earth to carry out an extension of the investigations, and that they must now take up what has been started and carried to a considerable distance by geodetic investigations. The gravity determinations over the Earth's surface are not nearly so complete as we shall hope to see them in the future, and we may hope that the newly founded International Union of Geodesy and Geophysics may pay as much attention to that question as the old Geodetic Association did in the past and probably even more. I should like to thank Sir Sidney Burrard for the very clear and interesting account of the theory of isostasy than he has given us.

Dr. MORLEY DAVIES: My interest in this subject is naturally from the geological rather than the geodetic point of view. The general theory of isostasy had been accepted by geologists some time before the time of Hayford: it was a geologist who first put forward the theory. Hayford's great merit was that he reduced it to a matter of actual calculation, whereas obviously it had before been a matter of mere hypothesis. But geologists are in disagreement as to the exact extent to which isostatic adjustment takes place. I think the most important work from the geological point of view is that done by the late Prof. Barrell, whose early death last year was so great a loss to American geology. His view was that while the theory of isostasy was perfectly sound and true as regards large areas, yet that many supporters of that theory had wished to apply it on much too small a scale to small areas; and he argues that the strength of the Earth's crust is considerably greater than some of the advocates of isostasy would be willing to admit. He pointed out that there is no evidence that such a large delta as that of the Niger had produced any depression of the underlying crust of the Earth. The overloading of that part of the sea bottom ought, according to the general theory of isostasy, to result in a depression, but the form of the sea bottom shows no evidence that depression to that extent had taken place. There are many other points I might refer to from a geological point of view, but that would be rather wandering outside the subject of this actual paper. One question on a matter of which I am ignorant. When Colonel Burrard spoke of Bouguer and his method of calculating gravity according to elevation above sea-level, did he really mean that Bouguer held the view absolutely that mountains were solid and rigidly supported, or assumed that as the easiest way of making a calculation, and that he did not consider the possibility of compensation coming in at all? That is a point on which I should be glad to have information.

Mr. R. D. OLDHAM: I presume I have been asked to speak on the geological aspects of this question, and I find considerable difficulty, because geology, at any rate as ordinarily understood, has nothing to do with isostasy, although the word did happen to be invented by a geologist. If we go back to the meaning of the Greek words it ought to be part of geology, but as the subject is dealt with in practice it is not so, nor does it seem to me that isostasy has any real connection with geodesy. It is rather a sort of "No man's Land" bordering on the two provinces, into which each party sends occasional raiding expeditions, and sometimes they come in contact with each other, resulting in a bit of a "scrap" which adds something to the interest of life if little to the sum of human knowledge. That is about all the connection isostasy has either with geology or geodesy.

A few years ago I did a little exploring of that sort myself, and I came back with a belief, not quite a conviction, but still a strong belief, that the word "compensation" as ordinarily used is a misnomer. When we speak of the mountains being compensated, I suppose it is natural to regard the surface irregularities of the surface as the primary fact which has to be accounted for and take compensation as a secondary thing. That is the attitude which has been assumed and tacitly accepted before now, and is most definitely taken up by Sir S. Burrard. I think it distinct service that that view should be put in a definite form so that it can be accepted or controverted. It gives a definite basis for argument. But though it is natural that a surveyor should take that view it does not follow that Nature works that way, and it seems to me that in reality the variation of density down below is the primary phenomenon, and the existence of mountain ranges and ocean depressions the result—in fact, the mountains are not compensated but are the compensation; but I think there is something beyond this, and that we have an example of the inevitable tyranny of words over thought. When we use the word "compensation" and speak of mountains as being "compensated," we cannot get away from the idea that the compensation is the secondary thing, that the mountains come first and the compensation comes second; but Archdeacon Pratt, to whom we owe the word, used it in a very much more precise and accurate form. He nowhere speaks of the mountains being compensated, it is the attraction of the visible mass of the mountains which is compensated by a defect of matter down below. He was not concerned in discussing which was the cause and which was the consequence, but it was clear that he definitely regarded what has come to be called compensation of the mountains as the cause of their elevation. His followers have been less precise and have turned the word "compensation" to a meaning which carries an implication different from Pratt's. Then there is the word "isostasy," which again has been much misused. If we speak of isostasy we ought to use it in the sense of Dutton, its inventor, with whom it was really almost a metaphysical concept. He based it on the acknowledged fact of Archdeacon Pratt's compensation, which had been applied and verified in America as well as the Himalayas, and from that he developed a principle that there was an inevitable tendency for every column of rock in the Earth to be of the same weight, and that if there is a change of weight by transfer of matter at the surface something takes place underground which makes a corresponding change underground in the opposite direction. That is the original meaning of the word as used by Dutton, but it has come to be used in quite a different sense, in America especially, and mainly in geodesy, as something practically synonymous with Pratt's compensation.

I do not know that there is anything more to be said on that question of

isostasy and compensation. But there is one other point. Sir S. Burrard has mentioned that various forms of distribution of this compensation or isostasy, are admissible provided they put the centre of effect at a depth of 25 miles. Now, outside geodesy and in any discussion of the origin of compensation the centre of gravity is a more important thing than the centre of effect, and the centre of gravity lies rather deeper than the centre of effect. That is rather an interesting point, because from 25 to 30 miles is a depth that we come across in many ways. In whatever way the problem is attacked the conclusion is reached that at about 30 miles' depth something very peculiar takes place in the Earth, there is a change in the constitution of the Earth, and I think it probable that those changes which give rise primarily to the compensation, if we may still use the word, and secondly to the differences of elevation of the surface are localized round about that depth. This, of course, is exactly the opposite view to that which Sir Sidney Burrard takes, as I understand his paper. He regards the compensation as a secondary result of changes which take place in the surface. It is a perfectly possible alternative view. I do not press the one, I do not object to the other, and he has certainly rendered service in putting his side in such a definite and unmistakable form.

Colonel E. H. HILLS: It seems to me that Colonel Burrard put the matter very clearly and proved his case, well, I may almost say up to the hilt. And what I should like now is for the geologists to tell us—which I have never yet heard a geologist do—how this condition of compensation really arises. How does an alteration of surface load transfer itself down into a difference of density at 30 miles and below? I understood Mr. Oldham to say he is quite equally prepared to believe that the surface configuration is either the cause or the effect of the difference of density.

Mr. OLDHAM: No, no. I said, I think, I had come to the opinion that they are the consequence.

Colonel HILLS: It appears to me, if the surface configuration of the Earth is the consequence of certain differences of density down below, it puts up a very difficult proposition to accept. These differences of density at a considerable depth must have arisen a very long time ago in the Earth's history, and must have arisen by accident; and to suppose that they give rise to the surface configuration is to me a very difficult thing. However, there is another point, and that is that Colonel Burrard and others who think with him maintain that isostasy is not a stable condition at all but a condition of equilibrium which is always altering, and therefore, if we have any deposit going on, such as in a delta or river, there is this compensation going on all the time. The condition is thus continually adjusted to one of equilibrium, and the difference of density at depth is a consequence, not a cause, of the surface configuration.

Captain G. T. MCCAW: I think, sir, we must be grateful to Sir Sydney Burrard for the clear exposition he has given us of the fundamental notions of isostasy. It seems fitting that the hypothesis of Archdeacon Pratt, who originated the theory in India, should be confirmed in India by a Surveyor-General of the great dependency. It might perhaps be interesting if some of the records more recently to hand were mentioned, and in this connection we have had recently a volume which contains a continuation of Mr. Hayford's researches. Apparently the mantle of Hayford—or at least the official mantle—has fallen on Mr. Wm. Bowie, to whose report I allude. As a result of pendulum observations at 216 stations in the United States, 70 per cent. additional to the previous investigation, he finds the depth of compensation to

be 60 instead of the 114 kilometres reached by Hayford. Bowie has divided these stations into groups, which show generally accordant results, with the exception of 56 stations in the mountain regions of the States, where the values are 95 and 111 kilometres, according to the assumption adopted. Since at stations above the general level in mountain regions gravity is very sensitive to change of depth, the author accepts a depth of 96 kilometres, which is practically the same as that derived by Hayford from observations of deviation of the vertical in mountainous regions. To the uninitiated it seems questionable to entirely reject the measures at the 160 stations of ordinary level.

A geological grouping leads to interesting results. The gravity anomalies above the Cainozoic deposits both in the United States and India tend to be negative. Over the pre-Cambrian formations, on the other hand, the results showed a great preponderance of positive results in the States, but in Canada no such rule obtained. Interesting too are the discussions on the Hayford anomalies at the coast and at points near together but of very different altitude. No doubt future investigation will concern itself largely with these conditions.

As Sir Sydney Burrard has shown, the Stokes or "free air" hypothesis gives much better agreement between observation and theory than Bouguer's formula (Young's Rule), indicating that Stokes' arguments in 1849 were sound, though not conclusive. But though Helmert originally followed Stokes, before his death he went over to the hypothesis of Pratt, who laid the foundations of the mathematical treatment subsequently completed by Hayford. Helmert's 1915 results, derived from 51 widely scattered coast stations, give a depth for the compensation of 118 kilometres. But these results were reduced by his 1901 formula, later revised by himself. Bowie shows that if Helmert's latest formula had been used the depth would have come down to 58 kilometres. It is interesting that Hulmert's new gravity formula considerably increases the value of equatorial gravity. He has, moreover, introduced a term which leads to an ellipsoidal earth, and it is at least curious that he finds the major equatorial axis at about 15° W. long., in close agreement with the Clarke ellipsoid, derived from geodetic measurements.

Major WOLFF: I have very little to say on the subject of isostasy. There is one small point that struck me, and that is the question of the way isostasy would affect the direction of gravity. Colonel Burrard mentioned the level of the sea. The surface of the sea is level, and presumably the direction of gravity is at right angles to that level surface, and the theory of isostasy seems to give means of determining their local direction, which will therefore affect the direction of gravity perpendicular to the level of the sea at the coast. Consequently, if you are levelling across a continent it does not follow that the point where you start and the point where you finish are on the same spheroid; and what I would like to know is, if you have a large mass of mountainous country, whether, from the point where you start or finish your operations, you would expect in levelling across from one side to the other to find a difference of sea-level due to the different direction of gravity, from the point where you started and the point where you came out. This has occurred to me on the spur of the moment as a question for discussion.

Mr. HINKS: May I first ask Captain McCaw whether the recent work of Bowie he mentions is connected with gravity pendulum survey such as is dealt with by Colonel Burrard, or a continuation of Hayford's work upon the deflections of the vertical?

Captain MCCAW: It is partly both. He has a considerable number of pendulum observations.

Mr. HINKS: They deal with rather different aspects of the matter, and I think the most interesting point in Colonel Burrard's paper is that, contrary to what I confess was my anticipation, he has put all his money upon the pendulum, and not referred to the deviation from the vertical, which form so very large a part of the literature of the subject and of his own original work. I should like to ask, in the first place, whether he has found in Helmert's writings any clear description of what was in Helmert's mind when he treated the visible mountains as if they were egg-shells with no mass inside them; whether what Colonel Burrard describes as compensation at sea-level had really, in Helmert's mind, any physical basis, or may be taken as merely symbolic, expressing the fact that in the computations he found he got a better result by merely neglecting the mass of the mountains. It is not quite the same thing as compensation at sea-level. But the more interesting point which I confess appeals very strongly to me is the question, what is really the evidence that there is this adjustment of compensation in a growing delta? All the results we have seen on the screen refer to observations made at the summits of mountains, and there are not, I think, in that list any gravity results in a delta, and yet it is said that the amount of silt brought down is compensated in some way. Geologists are a little shy in telling us whether it is things that are going on inside the Earth that make the rivers deposit their silt just there, or the other way round. It seems to me that it is like arguing which side of the balance balances the other side. But that is not the same thing as asking what is really the evidence for this continual adjustment to isostasy, because it is a good deal easier to imagine that in the process of building the Himalaya Mountains something may produce a compensation, than to picture the compensation of a gradually deposited delta. I would like to ask also whether Colonel Burrard thinks any light has been thrown by these pendulum results upon that question as to whether the effective depth of compensation is really uniform. It has always been felt as a difficulty that Hayford assumed a uniform depth, below which compensation may be taken as completely effective. I do not think any one who remembers the details of Hayford's five solutions would agree that Hayford had really shown there was anything very much better in one value than another of the depths he used.

Colonel BURRARD: Colonel Lyons asked whether the Italian and Austrian geodesists had found evidence in favour of isostasy. When you are dealing with Hayford's theory of isostasy, you have got to get all the maps of the whole world, and when you commence at any station you want the largest-scale maps, and as you go outwards you reduce your scale until you get to the Antipodes. The only countries so far that have calculated isostasy for their stations systematically are the United States and India. Europe has not touched the subject. It all remains to be done by the new Geodetic Union. The Swiss and the Italians have so far not made any such calculations.

Colonel Hills, although he modestly said he was an amateur, I think put a very crucial question to the geologists on the subject of deposits in deltas. In examining isostasy we first dealt chiefly with mountains, but recently I think the observations in the deltas have been most instructive. We have been puzzling over the observations on the delta and alluvium of the Ganges for years. I have also examined the Italian observations in the valley of the Po. Bowie wrote to me from America and said that the pendulum observations on the Ganges plains show that as the river deposits its new alluvium isostatic compensation takes place underneath, and this goes on adjusting itself all the time; all the most modern deposits in deltas are having their compensation

automatically readjusted in modern times. Dr. Morley Davies referred to the delta of the Niger, and I understood him to say that as a big river like the Niger deposits its delta, the extra weight ought to depress the crust. According to the theory of isostasy this is not the case. As the Niger deposits its extra alluvium the crust underneath will decrease in density; there will be no surface depression at all. As the extra load is poured into the delta of the Ganges, the density of the crust will decrease underneath. I think that one of the first systematic observations required is in the deltas of big rivers. If pendulum observations are taken in the Nile or Niger delta, will they show that isostasy is present? Prof. Darell says that the deltas of the Nile and the Niger are extra weights lying on the Earth's crust. Are they extra weights? Let us have pendulum observations. We may find that they have been entirely compensated underneath and that they are not extra weights at all. Major Wolff asked a question of which we have had some experience in India, namely whether, if you level from one coast to another, the presence of mountains will cause errors in the levelling. I am convinced we get no such error. It is probable that the ocean on the west of India is several feet higher than on the east owing to the western Ghat mountains, but the level does not show that because a level follows the geoid. When we were first levelling across India we got an error of 3 feet between Bombay and Madras, and that was ascribed to the attraction of the ocean by the western Ghats. When they levelled first from Port Said to Suez they reported a canal was impracticable, but all these discrepancies were due to faults in the levelling. Now when we level across India we find no difference in level between oceans. Mr. Hinks asked me why I put all my money on to the pendulum. I only want to keep my paper brief. I am not a bit frightened of talking of the plumb-line, but I am afraid of being too long. He also asked whether Helmert had any physical basis for concentrating his compensation at sea-level. I had the privilege of discussing this with Helmert on more than one occasion, and he had no physical basis; it was a mere mathematical assumption, which is discussed in his book on higher geodesy. He merely found that in dealing with pendulum observations, if he left out the last term in the formula, his results fitted the observed results better, and so he left out the last term, which was tantamount to assuming that compensation existed at sea-level.

Concerning regions which have shown recent geological activity, it is not safe to give a definite opinion as to whether observations in such places would be more valuable than in regions like Wales which are very ancient, but my idea is that observations in such localities would not be more valuable than elsewhere. I do not think you can obtain more valuable data now than by observing the pendulum and plumb-line in modern deltas, and by seeing whether they are extra loads or not. I believe that the deltas of the Mississippi and Ganges will be found not to be extra loads. I believe that as their silt is deposited, it is being compensated underneath at the same time.

Dr. Morley Davies asked if Bouguer really thought the mountains solid. He certainly thought them solid, and in his day all surveyors assumed they were solid. In India, when Sir George Everest was measuring the figure of the Earth, his southern arc joined his northern arc on a mountain range in Central India. He made most elaborate calculations of the mountain's attraction and he assumed it was absolutely solid; he ended the measurement of his arc on the plains of Lucknow instead of extending it to the foot of the Himalayas, because he was afraid of getting near to such a solid mountain mass.

The PRESIDENT: We are very grateful to Colonel Burrard for having given us such a clear exposition of this difficult subject. We are very grateful indeed to him, and I am sure you will all wish to give him a most hearty vote of thanks for his very valuable, interesting, and lucid paper.

THE RECENT EXPEDITION OF DR. HAMILTON RICE

THE Secretary has received the following letter from Dr. Hamilton Rice, who expected to reach New York about May 15 on his return from his latest expedition to the Amazons.

Manáos, Brazil, 18 April 1920.

I am taking advantage of the S.S. *Anselm's* departure to advise you of our safe arrival here a few days ago after an interesting and somewhat eventful voyage begun last September, which included an ascent of the Rio Negro to the Casiquiare canal, through the latter to the Orinoco, reaching Esmeralda 31 December 1919, from which point the Orinoco was ascended to the raudal (rapids) of the Guaharibos, where my little party of ten (including seven Indians) was attacked by a big band of Guaharibos, it being necessary to kill several of the attacking party in order to save our own lives.

As our armament consisted only of one rifle, a shotgun, a revolver, and a muzzleloader of 1799, it can hardly be said we advanced into the unknown Guahariba wilderness of the Orinoco headwaters with warlike intentions or preparations, and I would have infinitely rather conciliated the Guaharibos (the so-called white Indians) so as to have studied them and their ways; but there was no alternative, they being the aggressors, resenting all attempts at parley or truce, and compelling a defensive that resulted disastrously for them and was a keen disappointment to me.

I have the data for a fine map-traverse done on a scale 1/125,000—from Manáos to the Guaharibos rapids, with compass (7½-inch Navy and azimuth circle), ship's log, and time and distance scales. These are checked by more than forty astronomical stations, where time was obtained by our field wireless set by signals from Darien and Washington. In addition to obtaining the signals without difficulty day or night or practically in any kind of weather, a paper was printed each morning with the news of the world as sent out at 6 a.m. from Darien, so that we were always in touch with what was going on, in spite of the fact that we were in one of the wildest and most inaccessible regions of the western hemisphere.

Before I came away I read in one of your books* published by the Cambridge Press, a suggestion for adopting the Marcq St. Hilaire or New Navigation method for astronomical work in exploratory surveys, and found it served us well, for in such a country as this the climatological factors are such that the chances are nil during many months that the evening sky remains clear enough to catch the planned-beforehand pairs of N. and S. stars as they cross the meridian, or to get time-stars of suitable altitude and near enough to the prime vertical. By working out results from sights obtained on ideal nights by

* The reference is to 'Maps and Surveys,' C.U.P. (1913), page 62. For an interesting account of the application of this method see the recent paper on the Prismatic Astrolabe by Dr. Ball and Mr. H. Knox Shaw, *G.J.*, July 1919, 54, 37.

both methods for latitude and longitude they were in all cases so close as to justify the New Navigation method being employed when expediency compelled or conditions indicated such procedure.

I brought along two theodolites, of 5 inches and 6 inches respectively (Troughton & Simms), with electric attachments, and had special batteries made to resist dampness and the adverse climatic conditions encountered. A sextant was also carried for insurance, and both the Paget angle-sextant and the 3-angle sextant were found useful in augmenting the compass work.

Observations for azimuth and magnetic variation were taken at more than twenty of the astronomical stations. A complete set of barometric and thermometric readings has been kept, together with reports on clouds, wind, rain, etc., and I arranged to have similar readings taken at Para. The readings have been taken four times daily, 8 a.m., noon, 4 p.m., and 8 p.m.

Geology was not neglected, and I am now ready to put together the probable dynamic and geotectonic processes from which have resulted the present physiographical aspects of the Columbian Coqueta and Brazilian and Venezuelan Guayana.

The launch, which was planned and constructed to meet with the difficult conditions of navigation encountered in the Rio Negro, fulfilled expectations in every way, and certainly performed notable work in surmounting the bad rapids of the Rio Negro and the Casiquiare Canal and ascending the Orinoco to Esmeralda. From that point to the Raudal Guaharibos, the ascent was made by canoe. I am making over the launch to Dr. Thomas of the Liverpool School of Tropical Medicine, to be used as a floating laboratory in order to carry on a campaign against hook-worm and malaria, two of the curses of the Rio Negro.

Our microscope and big supplies of quinine were always in use, and an interesting survey of the diseases met with, etc., will form one of the not least valuable results of the expedition.

The school founded at São Gabriel three years ago has more than justified what was claimed it would do. The village to-day is clean, the children neat, clean, clothed, and well mannered; there are gardens, an abundance of food, and an increased population. Forty pupils have been graduated who are able to read, write, and cipher. They have some little knowledge of the history of Brazil, of geography, and of the form of government they live under; and each, instead of being an ignorant Indian slave at the mercy of unscrupulous traders, is a self-respecting independent individual doing well, knowing what he ought to receive for his work, and sufficiently equipped mentally to pass from the unproductive hunting and fishing stage to the next higher plane of existence.

The day of rubber is finished here, as are many of the attendant grisly evils that follow in its train, and in the present transition stage much may be done for the future good and prosperity of Brazilian Amazonas.

The priests are a power for good, and such work as Thomas has formulated is invaluable and deserves the financial and moral backing of all of us who are interested in the welfare of humanity.

The Rio Negro needs one or two roads at important or dangerous spots; it must have sanitation and elementary education for its people; then its emergence from a savage wilderness to a region of industry, agriculture, and commerce will commence.

HAMILTON RICE.

THE SCIENTIFIC DEVELOPMENT OF THE FALKLAND ISLANDS DEPENDENCIES

Report of the Interdepartmental Committee on Research and Development in the Dependencies of the Falkland Islands, with Appendices, Maps, etc. London: published by H.M. Stationery Office. 1920 [Cmd. 657]. *2s. 6d.*

IT has been evident to those who have followed events in South Georgia and the South Shetland Islands during the last fifteen years that the area included by the Dependencies of the Falkland Islands constitutes a national asset of great value, but that it would be unsafe to assume that it would retain that value if its exploitation were not subjected to some control. In 1904, as the result of Norwegian enterprise, a period of whaling activity on a scale far exceeding anything previously accomplished was inaugurated, by the formation of the Compania Argentina de Pesca, which began operations at South Georgia in December of that year. An expedition visited the South Shetland Islands, with similar objects, during the season 1905–6.

The pursuit of whales is an occupation of considerable antiquity, the Atlantic Right whale having been hunted in the Bay of Biscay at least a thousand years ago. After the numbers of this species had been very seriously reduced, as the result of operations in various parts of the Atlantic, the attention of the whalers was turned to the Greenland whale, at first off the coasts of Spitsbergen about the beginning of the seventeenth century, but later, when its numbers had declined in that neighbourhood, in Davis Straits; and at a still more recent period in the North Pacific and the adjacent parts of the Arctic Ocean. The Atlantic Right whale is said to have been saved from extermination by the discovery of the Greenland whale, which in its turn was reduced to a vanishing point in each of the three districts where it was successively hunted.

The Right whales so far considered, and the Sperm whale which was pursued in warmer seas, could be attacked successfully by small boats in the open sea. This was partly because their carcasses floated as a rule, so that the operation of stripping off the blubber could be carried out from the parent ship.

In 1865 a new era in the history of whaling was inaugurated as the result of the invention, by Svend Foyn, a Norwegian captain, of a harpoon fitted with a charge timed to explode on impact, which could be fired from a small cannon placed in the bows of the ship. This invention made it possible to capture the Rorquals or Fin whales, including the Blue whale, the giant of the group, which may reach a length of more than 100 feet. These whales had previously enjoyed a complete immunity from pursuit. The first Rorqual "fishery" took place in the Varanger Fjord, but others were started later off Newfoundland and in other localities. In every case the history of the operations has been identical, the period of prosperity with which they opened having been succeeded by a notable fall in the numbers caught, so that in most of the localities where whaling was once profitable the industry has become a thing of the past.

This was the position in 1904, when the vast schools of Sub-Antarctic waters began to be attacked. Modern methods can be most successfully employed when it is possible to hunt the whales at a moderate distance from shore and to tow their carcasses, artificially inflated with air, to land stations,

where the oil can be extracted from the blubber and the other products of the whales can be manufactured. For these purposes the island of South Georgia offered exceptional advantages, owing to the abundance of whales found off its shores and to the presence of good ice-free harbours where land factories could be erected. The South Shetlands possess one excellent land-locked harbour in Deception Island, but it has only one ice-free beach; and the preparation of the oil is accordingly carried on almost entirely by means of "floating factories," which are vessels larger than those used in hunting the whales and fitted with boilers for the extraction of the oil. At both these localities whaling has been extraordinarily successful, and in a single year the total catch of both together has exceeded 10,000 whales; a number which should be contrasted with 1437 Greenland whales captured in 1814, a year described by Scoresby as a specially good one.

Taking into consideration the admitted reduction of the whales in the districts previously hunted, and the fact that this reduction was accomplished by methods which would now be considered primitive, it was natural to regard the future of the Sub-Antarctic grounds with anxiety. This was all the more justified by the evidence with regard to the Humpback, a species allied to the Rorquals, but of smaller size than the Fin whale and the Blue whale which at present constitute the greater part of the catch. At the commencement of Sub-Antarctic operations, the Humpback was the principal object of the whalers' pursuit, having constituted more than 90 per cent. of the total catch in the seasons 1910–11 and 1911–12. In 1916–17 it fell to less than 10 per cent. There is some reason to believe that a contributory cause to its reduction has been the establishment of whaling off the coasts of Africa, South America, and elsewhere in Southern seas, leading to the destruction of considerable numbers of Humpbacks which may well belong to the schools that frequent Sub-Antarctic waters at other times in the year.

In 1917 the first practical steps were taken for the investigation of these and other questions, resulting in the constitution of an Interdepartmental Committee by Mr. Secretary Long "To consider what can now be done to facilitate prompt action at the conclusion of the War in regard to the preservation of the whaling industry and to the development of other industries in the Dependencies of the Falkland Islands." The Departments represented on the Committee were the Board of Agriculture and Fisheries, the Colonial Office, the British Museum (Natural History), the Department of Scientific and Industrial Research, and the Admiralty, with Mr. H. T. Allen, of the Colonial Office, as Secretary. The Chairman of the Committee was Mr. P. C. Lyon, C.S.I., and the result of its labours has been the issue of a Report containing much information with regard to the problems considered. Valuable help was afforded to the Committee by evidence given by authorities on whales, by representatives of the whaling industry, by Sir Napier Shaw, F.R.S., of the Meteorological Office, by Sir F. W. Dyson, F.R.S., Astronomer Royal, by Dr. J. W. Evans, F.R.S., Adviser on Geology to the Colonial Office, and by other experts. The assistance given by Dr. W. S. Bruce and Dr. R. N. Rudmose Brown, of the *Scotia* Antarctic Expedition, should be specially mentioned.

The Committee were fully in agreement with the scheme which had been indicated in the original terms of reference to employ a research vessel for the investigation of the numerous problems involved, but they arrived at the conclusion that it would be necessary to have two vessels, provided with motor-boats and the scientific staff, crews, and equipment necessary for carrying on the proposed researches as completely as possible. They con-

template an investigation which would last for a period of years. Provision is also to be made for publishing the scientific results of the expedition.

The section of the Report in which the Royal Geographical Society will probably be most interested is Part V., Hydrography. It is pointed out that our knowledge of this subject is exceedingly meagre, and that much geographical work remains to be done, in the preparation of accurate surveys of practically all the islands. The importance of this subject to navigation in these waters was specially emphasized in evidence given to the Committee. Uncharted rocks remain to be localized, while further evidence as to harbours, particularly in the outlying groups, is greatly required. Tides and tidal streams, ice-conditions, and deep-sea soundings are other subjects included in the scope of this part of the Committee's recommendations.

Part I. of the Report defines the area of the Dependencies of the Falkland Islands, amounting to about 3,000,000 square miles, and adds information with regard to the history, physical characters, and government of the islands, with notes on scientific expeditions which have visited these waters. The whaling industry, which occupies a considerable proportion of the entire Report, is next considered, the importance of whale-oil as a source of glycerine during the war being emphasized. This is illustrated by the statement that about three and a quarter million barrels of oil were produced during the nine years 1909–10 to 1917–18, valued locally at from ten to eleven millions sterling. Making allowance for the rise of prices during the war, the valuation exceeds twenty millions. Six barrels of oil are approximately equal to one ton. The great predominance of Norwegian participation in the industry is noted, and information is given as to the regulations in force for controlling it. The next sections indicate the species of whales captured, with remarks on their breeding and migration and on their food. In order to obtain definite facts with regard to migration, as well as to the rate of growth, the age at which the animals become capable of breeding and their longevity, a system of marking the whales is recommended, on the analogy of the methods which have been successfully used in connection with the fishing industry. Researches required to supplement existing knowledge are suggested, while other sections deal with the danger of depletion of the stock of whales, the future control of the industry, the introduction of British personnel, and the products of whales, with a special section on the possibility of utilizing whale-meat as human food.

The Report next proceeds to discuss the sealing industry. The Fur seal was formerly abundant; and it was stated by Weddell (see Appendix II.) that 320,000 individuals were taken during 1820–21 and 1821–22 at the South Shetlands, where the species was practically exterminated as the result of the operations of these two years. In the words of Dr. W. S. Bruce, "This is a most important economic disaster that should not be forgotten, and should at least not be allowed to be repeated (Appendix I.). A single specimen of this species was killed in South Georgia in 1915, and the Committee recommend that the attempt should be made to restock the earlier breeding-grounds by the introduction of specimens from other localities. The magnificent Elephant seal, hunted for its oil, is still taken in large numbers at South Georgia; but although there appears to be no immediate reason for anxiety on its behalf, the Committee are fully aware of the importance of watching events closely, and recommend that special attention should be given to its life-history and habits, and to the methods which should be adopted for hunting it.

Fisheries, penguins, and the acclimatization of animals in South Georgia are the remaining zoological subjects considered, special attention being called

to the success which has attended efforts to introduce the reindeer into that island, and to the regrettable increase of the brown rat, another colonist of the same locality.

The later parts of the Introduction deal respectively with Hydrography, Meteorology and Magnetism, Geology and Mineralogy, Botany, Research Vessels, Management of the proposed investigations and Finance, with a concluding part summarizing the Committee's recommendations.

The Committee think that the first cost of the two proposed vessels would be not less than £85,000, and that the maintenance expenses would be not less than £28,000 to £33,000 a year, which would provide for an adequate naval staff, in addition to five scientific members of the permanent staff. The probability that certain additional expenses would have to be contemplated is indicated. It is assumed that the vessels and survey equipment would be provided by the Admiralty, and that the cost of maintenance and the pay of the naval staffs and crews would be borne by naval funds. The hydrographic work, including surveys and the investigation of currents, tides, sea-temperatures, ice-conditions and soundings would thus be provided for. Economic development, including whaling, is a matter affecting the Dependencies, which may thus be expected to find most of the remainder of the funds; and it is proposed to raise the money required by increased taxation of the whaling and sealing industries. The executive control of the expedition is to be left in the hands of the Admiralty and the Colonial Office, the Departments through which the investigation will be financed. An Advisory Committee is to be set up, including representatives of these two Departments, of the other Departments represented on the reporting Committee, with the addition of a representative of the Board of Trade or the Department of Overseas Trade; and it should have the power to co-opt scientific experts in consultation with the Royal Society or otherwise; and also one or two other persons who have practical experience of the regions to be investigated and of the methods of conducting researches of the nature contemplated.

The writer of this review, who was himself a member of the Interdepartmental Committee, may perhaps be pardoned for thinking that the Report demonstrates the national and scientific importance of the proposed inquiries, and that it outlines a thoroughly practical scheme by which the expedition can be financed. The Appendices, which constitute the major part of the Report, contain a large mass of information which should be of the greatest use in facilitating the further development of the scheme. With regard to the whaling and sealing industries the Committee adopt a conservative attitude. While recognizing the urgent importance of preventing anything like extermination of the animals on which the industries depend, and also the possibility or even the probability that the number of whales captured during recent years has been excessive, they consider that the future regulation of both whaling and sealing should depend largely on the results of a scientific investigation of the subject on the spot. This examination is to be conducted on broad lines. It is already clear that the whales visit the Sub-Antarctic waters mainly to profit by the vast quantities of food found there during the southern summer; this consisting of "plankton," a term used to indicate collectively the animal and vegetable organisms, many of them of microscopic size, which float at or near the surface of the sea. Although the larger whales feed principally on small crustacea found in enormous numbers as constituents of the plankton, the *ultimate* source of their food consists in the main of microscopic vegetable organisms, and primarily of the plants known as Diatoms. The number of

these and their distribution depend on physical factors, such as light, temperature, and currents; and the whole whaling problem is thus closely associated with the study of these factors. The question is further complicated by the fact that whales undertake extensive migrations, more or less seasonal in character; and there is reason to believe that these are largely connected with the fact that some of them, and perhaps all, visit lower latitudes in order to breed and to bring forth their young in warmer water. The whaling industry of South Georgia thus has a direct interest in what takes place in the waters adjacent to the coasts of Africa, South America, Australia, and New Zealand. Much remains to be ascertained with regard to the rate of growth of whales, the age at which they become sexually mature, their breeding seasons, the length of their period of gestation, the frequency with which they produce their young, and the length of their life. On some of these questions evidence has been obtained by means of the statistical returns which have been furnished by the whaling companies for some years to the British Museum (Natural History). The Committee recognize the importance of this study and recommend its continuation.

The interest of certain other branches of the proposed inquiries is by no means confined to the area of the Dependencies. Attention may be directed to the work which has been done by Mr. R. C. Mossman on the correlation said to exist between the meteorological conditions of Antarctic regions and those of other countries as distant as South Africa, Egypt, and India. Tidal observations in the area of the Dependencies are also of the highest importance in connection with ocean tides in general. The accurate survey of the waters of the Dependencies should result in increased security of navigation, and would constitute a material advance in our knowledge of a large area which is at present insufficiently charted.

It may be hoped that the scientific societies will not be slow to recognize the unique opportunity which would be provided by the successful inauguration of the scheme recommended by the Committee, and that the Royal Geographical Society in particular will lend its influence in cordial support of proposals made not only for the development of the economic importance of a large area in which this country is directly interested, but also with the view of increasing our knowledge of many scientific problems which urgently require study. It may be added that the proposed expedition differs in one very important respect from others which have explored Antarctic waters. The area to be investigated is visited annually by a considerable whaling fleet, which will no doubt be utilized largely in obtaining evidence on some of the problems to be investigated. This is in itself a matter of considerable importance, but it has this further advantage, that, in the event of accidents occurring to the research vessels, it may be possible to find assistance near at hand.

SIDNEY F. HARMER.

REVIEWS

EUROPE

Middlesex in British, Roman, and Saxon Times.— M. Sharpe. London: Bell. 1919. 12*s.* 6*d. net.*

APART from a brief account of the pre-Roman antiquities of the country, and a description of the ford at Brentford where it is now generally agreed Cæsar crossed the Thames, this work is devoted to an attempt to determine the

character of the land settlement in Middlesex in Roman and Saxon times. The Roman survey is traced by reference to ancient rural ways, sites of compita, bobontini, and other landmarks, place-names, etc. In the suggested continuity of the Roman and Saxon settlements, the centuria becomes the virgate, the vicus the vill, the pagus the hundred : the thane takes the place of the emperor, and geneats, cosetlas, and geburs represent tributarii, contributi, and coloni. The author illustrates his conclusions by several maps. Some of these would not have suffered had they been on a larger scale. One of them embodies the interesting suggestion, resting on somewhat slender evidence, that no fewer than forty-seven churches stand on the sites of Romano-British pagan chapels or compita. The book concludes with the inevitable reference to Domesday, that invaluable check on all speculation regarding land settlement in pre-Norman times. E. A. P.

ASIA

A Geography of Asia.— **Joseph Martin.** London: Macmillan. 1919. 5*s*.

This book is one of Macmillan's Practical Modern Geographies, and nothing more need be said to indicate the quality of the map-making and printing. Mr. Martin divides Asia into four areas: South-West Highlands from Baluchistan to Smyrna; the Monsoon Region; the Mid-Asian Deserts and Steppes; Northern Asia. His grouping brings the whole of India, China proper, Japan and the East Indies with Siam and Malaya into one *region*, that of the Monsoons, and provokes inquiry as to what, in his view, the term "monsoon" covers.

On p. 57, the Monsoon Lands are classified thus: (*a*) Temperate: north of the Hwangho, cold winds, wheat grown; (*b*) Sub-tropical: south of China and Japan—mild winter, hot and wet summers, rice grown; (*c*) Tropical: India and Indo-China—warm winters, very heavy summer rains; (*d*) Equatorial: East Indies and Philippines—always hot, heavy rains with both monsoons. Figs. 27 and 28 show "Asia: Winds and Rainfall," for the periods May—October, November—April. The wind directions are here too highly generalized, for the best authorities show no such definite indraught from the Pacific as is at all comparable with the summer indraught from the Indian Ocean.

On pp. 55–56 it is asserted that "the strength of the inflowing summer monsoon is greatly increased by the presence in Central Asia of the lofty and extensive plateau of Tibet." Mr. Martin subscribes to the Central Asian furnace-flue hypothesis in a modified form, and bases his argument in part upon the somewhat venturesome assumption that the temperature of the atmosphere falls 1° Fahr. for every 300 feet rise in elevation. The author does not appear to attach much importance to the climatic divisions of Herbertson and Köppen, to the possibility that heavy summer rains may occur in other ways than in connection with a presumed indraught of oceanic air, or to the relationship between rainfall and the average direction of cyclonic storms roughly parallel to the lie of Japan in the one case, in contrast to their direction up the Ganges valley in the other case.

Apart from this general question of outlook over the whole continent, the treatment and arrangement of the individual facts provide the student with considerable information, attractively presented, concerning Asia.

B. C. W.

AFRICA

Zanzibar—The Island Metropolis of Eastern Africa.— Major F. B. Pearce, C.M.G. London: Fisher Unwin. 1920. Pp. 421. *Maps and Illustrations.* 30*s. net.*

This book goes a long way to supply a much-felt need. The author has been at pains to bring together all the information he could cull from books ancient and modern as well as from stories and traditions collected by him on the spot. Thus equipped, he has given us as complete a history and guide-book of the Sultanate as up-to-date knowledge affords. Moreover, he has contributed a most interesting account of the ruined buildings which are dotted about the coasts of the two islands, so providing matter hitherto unpublished and of a kind likely to be helpful in filling the existing gaps in the early history of East Africa. Included in the volume is a chapter on the Natural History of the Islands by Dr. W. Mansfield-Aders, an officer of the Zanzibar Government, whose careful observations have enabled him to introduce at least one new quadruped to science—an Elephant Shrew (*Rhynchocyon adersi*). The book is divided into three parts, the first being devoted to an account of the several historical phases of the islands; the second to their present condition; and the third to a description of the ruined buildings. The text is illustrated by excellent reproductions of photographs.

The earliest reference to the islands rests upon the hypothesis that the island called Menuthias in the ancient ship's log known as 'The Periplus of the Erythræan Sea' was either Zanzibar or Pemba, as suggested by W. H. Schoff in the scholarly notes to his translation of the Periplus. The present author leans to the opinion that it was Zanzibar, for reasons which are not wholly convincing. It will probably remain a moot question to the end of time which, if either, of the two islands was called Menuthias by the early navigators.

The considerable areas covered by some of the ruins has led the author to surmise that they were "the substantial and permanent abodes of thriving merchants and communities." It seems more likely that the buildings were used for the temporary internment of the slaves bought or captured on the mainland, as well as for safeguarding the ivory, gold, and other valuable commodities awaiting shipment—a theory based on the idea that as the sea-traders from the north extended their voyages southward along the East African coast, they found it necessary to establish two independent sailing fleets: one to sail forth and back between Zanzibar (or Pemba) and Sofala, and the other between the islands and the Arab ports in the Persian Gulf. Under this arrangement the crews of the ships of both fleets would have had sufficient time to careen and refit their vessels, as well as to disembark and take in their cargoes, at the emporiums situated on the islands. To have sailed all the way from the Persian Gulf to Sofala on the north-east monsoon and back on the following south-west trade wind would scarcely have allowed the time required in port. The ruins are mostly situated on waterless islets, and the people who occupied the buildings were therefore under the necessity either of cutting tanks in the coral rock for catching rain-water, or of making constant short journeys by boat or canoe to the nearest freshwater springs. Places so ill provided with fresh water are scarcely likely to have been centres of thriving communities. On the other hand, such spots would afford good facilities for embarking and disembarking slaves and merchandise: they could easily be defended by small garrisons, and slaves interned there would be safe against escape.

Trenches carefully excavated across the sites of some of the ruins, and sunk deeply enough to expose the lowest foundations, might show whether the build-

ings now visible were raised upon the remains of yet earlier structures, and might also bring to light human implements—thus carrying us a step further in our knowledge of the early history of the islands. But work of this kind should not be put in hand unless skilled supervisors are available to conduct the operations. F. R. B.

AMERICA

Men, Manners, and Morals in South America.— **J. O. P. Bland.** 8vo. Pp. viii. + 319. London: Heinemann. 1920. *Price 12s. 6d. net.*

The author, who is well known as a student of China, and who in collaboration with Mr. E. Backhouse wrote 'China under the Empress Dowager'—as interesting a book as was ever produced—went two or three times to South America during the war on some British Government mission "with certain subsidiary purposes of propaganda." From his experiences he has undertaken to write, on the wide subject of his title, a book which shall not be so "stodgy" as those of Koebel or Foster Fraser, and not "so obsessed by the commercial and industrial possibilities of the country" as those of M. Clémenceau and Viscount Bryce! It is so stated in his introduction. The outcome of his ambition is a book which combines, with some pleasant and interesting remarks on his avowed subject, a great deal on "the ignominious eclipse of Germany's pinchbeck and poisonous Kultur," and much more of reflections upon British politics and conduct of the war: the latter scarcely compatible with his position in the confidence and employ of those whom he abuses. If this were only cleared away the merits of his observations on the peoples of America would be more plain. As it is, when he gets away to the *estancia* he is interesting; when he writes on the politics of the town he cannot refrain from backhanders, as "the nature of the flapdoodle with which masses of foolish electors are fed requires careful selection. . . . The stuff that Sun-Yat-Sen ladles out to Young China, for example, would not suit the digestion of the cultured millions who swallow the sophistries of Mr. Wilson." The author's style has indeed suffered during the war. He calls the police "sword-bearing siesta experts"; he writes of "the mole-hill eminence of the Cerro, which is the name of the Monte which the Spanish navigators video'd"; and prize cattle are the "Pashas of the bovine aristocracy." There is useful information and original observation in the book; but it is bad to read, and we do not think that it will supersede the others.

The Great South Land.— **W. H. Koebel.** London: Thornton Butterworth. 1919. *15s. net.*

This volume by Mr. W. H. Koebel, the author of over half a dozen descriptive books dealing chiefly with the more modern phases of the South American Republics, is pleasant and readable, without striking any particularly new note. Possibly it was not meant to do so, but rather to crystallize, for the benefit of his readers, the impressions of a stay in Argentina, Uruguay, and South Brazil, towards the end of the war, and after the armistice was declared. Mr. Koebel chiefly describes the social and political conditions in the three countries, which were at that time in a state of even more rapid transition than these mercurial lands have been accustomed to in the past.

It is perhaps inevitable, under such circumstances, that the author should deal mainly with the interplay of forces at work in the capitals of the Republics described. This comprises the more "popular" and also the larger portion of the book, interspersed with anecdotes which make cheerful reading for those who espoused the Allied cause. Just how far life in Buenos Aires,

Montevideo, and Rio de Janeiro is a true reflection of the sentiments or progress of the people living outside these cities, is a debatable point which need not be discussed here. Sub-sections of the book review the resources of the great territories which give these capitals their real importance, and without going into detail (which would be impossible in dealing with so large an area) Mr. Koebel manages to convey a fairly accurate impression of the country covered.

Those who have a more intimate business or personal acquaintance with the Southern Republics will regard the facts given in the book as current knowledge. But there is still a large public on this side which is extremely vague in its ideas, and to this the book may be recommended. It will be news to many that Brazil has a very highly developed cotton-manufacturing, as well as a cotton-growing industry. The lessons of the war brought home to most our dependence on the Argentine for wheat and meat, but that Brazil again has nearly one head of cattle for each of her twenty-eight million inhabitants is another economic fact which is in danger of being overlooked.

While 'The Great South Land' would be an uncertain guide for demobilized officers with a limited capital, proposing to rehabilitate their fortunes in that El Dorado, it serves a useful purpose in keeping alive our interest in these countries as increasingly important political and economic factors. Their governments should certainly be grateful to Mr. Koebel for the South American literature he continues to present to the British public in so readable a form. The book is well printed, and has a useful index.

W. S. B.

MATHEMATICAL AND PHYSICAL GEOGRAPHY

Problems of Cosmogony and Stellar Dynamics.— J. H. Jeans, M.A., F.R.S. 8vo. Pp. vii. + 293. Cambridge University Press. 1919. 21*s. net.*

This book is full of most formidable mathematics, and geographers will be among those readers who will find the more speculative chapters at the end of the book the most interesting, and will be grateful to the author for his attempt "to arrange the book so that they will prove intelligible to those who prefer to take mathematical investigations as read." With a modesty unusual in cosmogonists, Dr. Jeans professes that his own contribution forms but a small part of the theory; that his own scheme of cosmogony is suggested, not in the belief that it will prove to be true, but in the hope that it may lead others to find the truth; and that this scheme contains nothing fundamentally new, but is only a patchwork of parts of existing theories: a theoretical investigation such as that of the present book is necessarily destructive rather than constructive.

Of its destructiveness there is no doubt. The critics who have attacked Laplace's Nebular Hypothesis are routed. The celebrated disagreement between George Darwin and Liapunov on the stability of certain forms of rotating bodies is explained by the proof that they were both wrong. The much-vaunted "planetesimal hypothesis" of Chamberlin and Moulton is shown to be untenable as a normal process; and "it seems probable, though by no means certain, that we must abandon the Nebular Hypothesis of Laplace" as explaining the origin of the Solar system. But by a brilliant constructive development of it Dr. Jeans explains spiral nebulæ, star clusters, and binary stars, though "there is no room on this chain for systems like our own." He therefore examines the possibilities of tidal evolution, with promising results for the planets of the Solar system and some of its satellites, but not for others.

"The system which interests us most nearly, namely our Earth-Moon system, is just the one about which it is most difficult to come to any definite conclusion. For the Earth-Moon system is exceptional in the system of the planets, just as the Solar system to which it belongs appears to be exceptional, and, for aught we know, may be unique in the system of the stars."

With these words the author concludes a masterly book. Very few mathematicians could profess to understand it all ; but the conclusions are so clearly put, are so arresting, and bring so much order into what had been chaotic, that it must command a wide circle of interest. Geographers as well as astronomers will welcome a strong lead in regions full of pitfalls, where false tracks are innumerable, and the way obscure.

Though the general theory must bear on the problem of the figure of the Earth, this is not treated explicitly in the present volume. But it may be well to call attention to Dr. Jeans' refutation in a recent paper (*Proc. R.S.*, A, 93, 1917) of a theory of his own which has been quoted in text-books. In the *Phil. Trans.*, Ser. A, 201, 1902, he obtained results suggesting that the Earth had solidified from one of the pear-shaped figures of stability (as then supposed) ; and the theory of the "pear-shaped" Earth with "stalk" at the south pole won some celebrity. In the more recent paper he satisfies himself that this was one of the false tracks ; "the attempted explanation of the Earth's dissymmetry of figure fails entirely." A. R. H.

Accounts rendered of Work done and Things seen.— J. Y. Buchanan, F.R.S. Cambridge: University Press. 1919. Pp. lviii. + 436. *Illustrations.* 21*s. net.*

This is a continuation of Mr. J. Y. Buchanan's edited reprints of his scientific papers and literary articles, the large number of pages with roman numerals being filled with the ingenious analytical index of the works which follow.

The first item of the accounts rendered is Mr. Buchanan's introductory lecture inaugurating the geographical lectureship at the University of Cambridge. Its theme was communications and population, and he explains in the new introductory matter that he chose it because he was born in 1844, at the time when the first railway systems of Europe were developing, and just before his appointment to Cambridge he had paid two long visits to the Argentine Republic at the time when the railway system of that country was revolutionizing its economic life. To the enthusiastic appreciation of railway enterprise evinced in the lecture of thirty years ago the author now adds a rather mournful postscript, setting forth the price paid in the destruction of primitive faunæ and primitive peoples.

Most of the longer papers which follow deal with oceanography in its historical aspect and in relation to the author's own researches. They are all full of interest and originality, though some are almost provocative of controversy. We cannot, for instance, accept Mr. Buchanan's birth certificate of oceanography, even although he was present at the alleged event. He says (p. xiii.), "Consequently it may be taken that the science of Oceanography was born at sea in lat. 25° 45′ N., long. 20° 14′ W., on 15 February 1873." We are inclined to the belief that the science of Oceanography came into the world much earlier, though its origin was obscure and its infancy much neglected. The article on lakes from the 9th edition of the 'Encyclopædia Britannica' deserves a postscript, for it serves as an excellent *résumé* of what was known before the limnological surveys of the last forty years supplied the wealth of data which now exists. So also we would gladly have seen a farther develop-

ment of Mr. Buchanan's work on the temperature of Loch Lomond and Loch Katrine. But the fact that we ask for more must be construed as an expression of gratitude for what Mr. Buchanan has given us. The two volumes of collected and annotated papers will prove extremely valuable to future historians of nineteenth-century oceanography. H. R. M.

GENERAL

The World's Meat Future.— A. W. Pearse. London: Constable. 1920. 21*s. net.*

Mr. Pearse, the editor of the *Pastoral Review*, is qualified to write on the world's meat trade by personal knowledge, gained during a period of some thirty years in the majority of the great meat-producing areas. His survey, which excludes the continent of Europe, is replete with valuable information, useful alike to the economist, the trader, and the geographer. The livestock industry of Australia needs reconstruction, and the author's scheme involves "reasonable legislation and moderate taxation," lower railway rates, and the removal of shipping embargoes. It is suggested that Indian zebu stock would improve the grazing industry of the northern territory. New Zealand is the stock-owner's paradise. Argentina is the main exporter of frozen and chilled beef in the world, with Brazil as its chief competitor. In 1915 Brazil exported 8000 tons of beef; in 1917 over 66,000 tons were sent abroad: these are the beginnings of a new industry. The chief states are Rio Grande do Sul, Minas Geraes, Goyaz, Matto Grosso, and Parana. "As regards live-stock, the United States is not by any means as spent as it was generally supposed to be." In South Africa both cattle herds and sheep flocks are increasing steadily. British South Africa used to import meat, but became an exporter in 1914. At the end of the book is a useful list of refrigerating works, etc.

Much of this book is outside the scope of geography, yet its sternly practical tone and the numerous sketches of geographical conditions make it a useful supplement for the economic geographer to the official and commercial statistical summaries. B. C. W.

THE MONTHLY RECORD

EUROPE

Snowfall Studies in the Northern Appenines.

STATISTICS available for three stations on the lower slopes of the Northern Appenines for a period of from twenty to thirty years form the basis of an interesting study published in the *Rivista Geografica Italiana* for January–March 1920 by the late Signor G. Anfossi. The stations are: Le Lavezze at an altitude of 652 metres, Sestola, 1096 metres, and Modena, near sea-level below Sestola, under a similar climatic *régime* to that of Sestola in all factors except altitude. It is found that the proportion of snow to rainfall in the total annual precipitation increases by 2 per cent. for every 100 metres (*circ.* 300 feet) of ascent. Regret is expressed by the author that data do not exist for higher altitudes, because it cannot, of course, be assumed that this rate of increase remains constant. But as regards horizontal variation, it is shown that this coefficient is confirmed for regions in both the French and Swiss Alps. The seasonal aspect of the subject is interesting. Thus at Modena, where very little snow falls at all, the month

with most snow is January, the coldest, but at the higher altitudes the amount of snow which falls is governed more and more by the total amount of precipitation. This feature also is shown to be confirmed by observations in the French and Swiss Alps, and is there brought out more prominently still. Thus on the Great St. Bernard January is a month of minimum snowfall, flanked by maxima in April and November. This is because the Alps lie in the Central European zone of higher summer than winter rainfall, so that the times of actual greatest snowfall are determined by the general rainfall and temperature factors combined. It is to be regretted that no such snowfall coefficients are available for mountainous localities in the British Isles. In a country like England, where much of the winter precipitation is on the borderland between rain and snow, nothing is more striking than the manner in which the least elevation tells in the matter of the lying of snow.

ASIA

Mr. Raeburn's Expedition to Kangchenjunga.

Mr. Harold Raeburn, known for his mountaineering explorations in the Caucasus in the summer of 1914, which he described before the Society in the following January (*Journal*, March 1915, pp. 181 *et seq.*), sailed for India early in June on a new expedition, to Mount Kanchenjunga. So late in the season he does not expect to achieve more than a reconnaissance of the mountain, but we may look for some results of value if he escapes the misfortune which befel Mr. Freshfield and his party in 1899, in the form of a tremendous snowstorm of forty hours' duration, making any attempt at high ascents impossible.

Silt of the Euphrates.

In a communication received from Lieut.-Colonel H. Stevens, of the Mesopotamian Expeditionary Force, attention is called to the vast amount of silt carried by the Euphrates as shown by the complete filling up of a "borrow-pit" (an excavation from which earth has been removed for the construction of bunds) by the overflowing of the river during the three months in which the floods come down annually. Our correspondent sends a photograph showing the conditions at the spot after the fierce sun of summer had caused the surface to crack in a network of fissures. He says that not only is it possible to see the total amount of silt deposited during the three months (an average of 5 feet), but also how much was deposited on each day, as the layers are very well defined. He considers that the deposit of such an amount of silt in so short a time is an indication of the silt-carrying capacity of the Euphrates, though he allows that it must not be taken as having any relation to the amount deposited generally on the area of the floods, as the flood-water would naturally not remain so long stationary in the open country as in an enclosed pit. It certainly seems that caution is needed in building any general conclusions on the facts stated, for it would seem only likely that in breaking through its banks the river would carry much silt into the pit from the immediate surroundings, and that when once so trapped, as it were, it would not easily escape again. From the photograph it hardly appears likely that the thickness of the layers can be measured to any considerable depth below the surface.

A Journey across Borneo, from Bandjermassin to Kuching in Sarawak.

We have received copies of the *British North Borneo Herald* for 16 June and 1 July 1919, containing a short account of a journey across the whole width of Borneo from south-east to north-west by Mr. B. W. E. Massey,

reprinted from the *Sarawak Gazette*. Leaving Bandjermassin on 17 October 1918, Mr. Massey ascended the Barito by steamer to Purok Tjahu, the last Dutch Government outpost in those parts, proceeding onwards with one large *prahu* and five coolies for Tumbang Djuloi, at the head of the Barito proper. The river flows in part through broken hilly country, and there are five great rapids involving the emptying of the *prahu*. The riverside villages are at first Malay, but higher up those of the interior tribes of the Siang, Murung, Ut Danum, and Pari are met with, side by side with some still inhabited by Malays. Of these the Ut Danum are much fairer skinned than the Murung, and of those seen only the men were tattooed. Tumbang Djuloi is a large village mainly of Malay traders who buy up the jungle products from the Barito headstreams to sell in Purok Tjahu for the Bandjermassin market. Mr. Massey continued his voyage with three small *prahus* by the Djuloi and Busang rivers, the rapids in the latter being too bad to permit their ascent in larger boats. From a point on its course a full view can be obtained of the magnificent waterfall of the Mubung, formed where it flows over the escarpment of the Gunung Hau. The country is not inhabited by any regular population, and for five days not a soul was seen. Higher up there were clearings made by Malays and Kenyabung Punans from Tamaloe, the largest village on the Busang, though nearly deserted when reached by Mr. Massey. Hence the Tamaloe river was ascended to the last Kenyabung village of Sabaoi (December 4), where four natives were obtained as guides over the mountains which form the main watershed of Borneo. They are for the most part devoid of any track beyond the slight paths of Punan hunters, and the route lay in great measure up the beds of mountain torrents. A night was spent on the top of Gunung Petcha Pinggan, one of the highest summits of the range, where the cold was intense, but atoned for by the fine panorama of mountains, among which the Gunung Saung is distinguished by a precipice of white rock near its apex. The natives regard it with dread, and tell tales of dammar collectors being burnt to death by fires which burst out at a spot below the precipice. The descent led to the headwaters of the Kerihau, still peopled by Kenyabungs, but as famine was raging here as on the other side of the watershed, the party was for some time on short commons. Towering white cliffs like those of the Busang were seen in the distance, and the river probably passes between them, no route along its banks being possible. Having procured a boat Mr. Massey reached Putus Sibau on the Kapuas river, and passing the Sarawak boundary on December 16, was hospitably received at the station of Simangang, whence Kuching was reached on December 29. Mr. Massey speaks enthusiastically of the birds, butterflies, and orchids seen in the mountains, but the food shortage made collecting impossible. As far as the headwaters of the Barito the route was that taken by Carl Lumholtz in 1915 (*Journal*, vol. 48, p. 430), but from the Busang the latter traveller crossed the mountains northward to the Mahakam, which he descended to the east coast.

AFRICA

Ruwenzori.

Ascents of Ruwenzori are still sufficiently uncommon to make it of interest to record them. A letter from Mr. W. Younger, Assistant Superintendent of Police, Fort Portal, tells of an ascent which he made at the end of last year with Mr. Clifford Henry, the District Commissioner. Leaving Ibanda on December 27, they followed the route of the Abruzzi expedition and of the British Museum expedition of 1906 by the Mubuku valley and the Moore glacier,

eventually reaching the rocky boss or "knob" on Kiyanja, which was climbed by Messrs. Wollaston, Woosnam, and Carruthers. The record of this ascent (April 1906), together with that of the Duke of the Abruzzi in the following June, was found in a tin inside the cairn at the top. From many points of view this appears to be the summit, and Dr. Wollaston's party were under the impression that they had reached the highest point until a clearing in the fog revealed a snow-covered point about a quarter of a mile to the north as about 150 feet higher. This is the Edward Peak of the Duke of the Abruzzi, but his book does not mention the ascent of the rock on which his record was deposited.

AMERICA.

Dr. Hrdlička's Ethnological Researches in Florida.

The annual report for 1918 of explorations carried out under the auspices of the Smithsonian Institution (*Smiths. Misc. Collns.*, vol. 70, No. 2) contains a brief report of a four weeks' exploration by Dr. Aleš Hrdlička of the little-known region of the Ten Thousand Islands on the south-west coast of Florida, supplementing previous work by him in the same peninsula. The objects were to trace the anthropological type of the former aboriginal population, and to study such Seminole Indians as might be met with. It had been supposed that the coast region south of Key Marco possessed few aboriginal remains, but it was found on the contrary to be full of sites, shell-heaps, platforms, and mounds, with canals and other evidences of former Indian occupation, the remains covering sometimes 20, 30, or even 80 acres. All these await scientific exploration. Though with some interesting differences, the remains seem all to represent the same culture and people, to be identified with those farther north, up to and beyond Charlotte Harbour. A section was known historically as the Caloosas. Judging by their skulls they were a homogeneous stock, physically related to the type of the Eastern Algonquins, the round-headed people of farther up the coast being here wholly absent. Of the Seminoles, four individuals were met with, two of full blood. These people roam over most of the Everglades and the myriad keys of the coast. They are partly civilized, though preferring to be left alone, and show a considerable mixture with whites, and slightly also with negroes. The same report, which is fully illustrated from photographs, contains an account of archæological field-work in Colorado, Utah, and Arizona by Dr. J. W. Fewkes and others.

Cotton-growing in South America.

In the search for new supplies of raw cotton—one of the most urgent economic needs of the present day—attention in this country and France has been directed principally to Africa, where the protectorates in the Sudan and elsewhere afford a promising field for the extension of cotton cultivation. But South America offers similar possibilities, which are likely to be attractive to peoples not possessed of African colonies. Such possibilities are discussed in the *Geographical Review* for January of this year by G. M. McBride, who points out that though the commercial output is still almost negligible and from two countries only—Brazil and Peru—efforts to increase production are being made in earnest. In Peru cotton was an important cultivation long before the arrival of the Spaniards, and had led to great progress in the textile art among the ancient inhabitants. As in Egypt, it is here a desert crop, helped by irrigation from the streams flowing from the Andes, though in the far north the occasional rains permit growing it without such aid. At present about 140,000 acres are planted in cotton, and

this area is capable of considerable extension. But it is the extensive uplands of Brazil and the plains of Northern Argentina that offer the greatest possibilities. In Brazil the cotton plant grows wild or cultivated over the whole republic, though production for commercial purposes is limited almost entirely to the states along the north-eastern coast, a small district west of the city of São Paulo, and a few localities among the hills of Minas Geraes. It is distributed chiefly on the highlands bordering the coastal belt between the 500-feet and 2000-feet contours. The cotton districts have a semi-arid climate, and liability to droughts, especially in Ceara, will call for irrigation by storage if cultivation is to be increased. The future of cotton in Brazil has been forecasted by some in extravagant terms. Climate and soil conditions would no doubt permit great extension, but labour and transport difficulties are serious obstacles. Still more is this the case in the otherwise suitable parts of Northern Argentina, Bolivia, and Paraguay, which together form an area greater than that of the cotton-belt of the United States. But these problems are no doubt capable of solution, and the writer thinks that South America may in time compete with North America, Egypt, India, and China in supplying the most important article of international trade.

AUSTRALASIA AND PACIFIC ISLANDS.

An Exploration of the Groote Island Group, Gulf of Carpentaria.

Probably no part of Australia has remained so long untouched by outside influences as the island group on the western side of the Gulf of Carpentaria, of which the principal unit is the Groote Eylandt of the early Dutch navigators, shown on the very first charts of this region, but more or less neglected from that day to this from its position off the main routes of traffic. An exploration of the group was made in 1916 by the Rev. H. D. Warren, Superintendent of the Roper River Mission in the Northern Territory, accompanied by Mr. A. J. Dyer. The trip, of which an account appears in the *Victorian Geographical Journal*, vol. 34, 1918, was made in the motor launch *Evangel*, and involved considerable difficulty from the stormy weather encountered, the dangers of the coral-strewn sea, and by the trouble caused at times by the launch's kerosene-driven engine. Flies and mosquitoes, too, were a frequent cause of discomfort. From the Roper river the route led north along the coast to the mouth of the Rose river, where a site for a new mission station with good water supply was selected. Here some large wooden idols made by the blacks were examined. The first island visited was Bickerton, where men from Groote Island were already met with, distinguished from the rest by the cut of their beards. The island is largely made of bare rock, with little grass, but has a good deal of cypress and other timber. It seems to support no animals and few birds. Woodah island, further north, has a poor sandy soil but some grass, and a good site for a station was seen on the east side. The coast is, however, exposed and not suitable for steamers; a heavy swell was encountered at the time of the visit. On the way to Groote Island (course south-east) a strong current was found to set between it and Connexion Island, which divides into two the channel between Groote and Bickerton Islands. On Groote Island the country bore a different aspect to that previously seen, consisting of ridges separated by green gullies. It was completely circumnavigated, and a good deal of the interior examined, though the native "boys" were in great dread of the wild blacks of the island. The north point as shown on the charts was found to consist of a chain of islands. The island is mostly barren rock, but some good grass flats were seen, with large stringy-bark and other timber. Kangaroos

were met with and cockatoos and other birds seen, while fish was to be had in plenty from the sea and turtle eggs were procured on land. The island is some 35 miles in length by 25 in breadth, and its centre is occupied by a mountain 600 feet high, which was ascended and a splendid view obtained from the top. Copious and fast-flowing streams with fern-covered banks descend on both sides, and on one which debouches on the west coast an excellent site for a station was found. On another creek further north there was a big waterfall, and though the banks were 50 feet high there were signs of floods having risen high above them. At Connexion Island, during a severe storm from the south-west, the engine was swamped and the launch was for some time in great danger on a lee shore of coral. The return was made by the south side of Bickerton Island, in the teeth of continued storms and a terrific sea.

GENERAL

Readership in Geography at Manchester.

We learn with regret that Mr. Alan Ogilvie, after holding the position for only one academical year, has resigned the Readership in Geography of the University of Manchester to join the staff of the American Geographical Society of New York.

Summer School for Geography Teachers at Bangor.

We are informed that a summer school for teachers of geography will be held at the Normal College, Bangor, from July 31 to August 14, and will be conducted by Mr. Wallace E. Whitehouse. There will be short courses of lectures, map-work classes, and excursions in the Snowdon district. This is the third year in which such a school has been arranged. Further particulars may be obtained from the Principal, Normal College, Bangor.

The National Geographic Society.

At the last Annual Meeting of the Board of Managers of the above Society, Mr. Gilbert Grosvenor, for twenty years Director of the Society, was elected as its President in succession to the late Rear-Admiral J. E. Pillsbury, U.S.N. Mr. Grosvenor graduated at Amherst, Mass., in 1897, after a distinguished college career, and a couple of years later entered the service of the National Geographic Society, which during his directorship has increased its membership from 900 to 750,000, besides developing its activities in many directions and establishing itself in its present handsome buildings in Washington. Mr. Grosvenor has a country estate near Bethesda, Maryland, which forms one of the most remarkable bird sanctuaries in the United States.

OBITUARY

Captain Ettrick William Creak, R.N., C.B., F.R.S.

WE much regret to record the death of Captain E. W. Creak, R.N., C.B., F.R.S., which took place at Blackheath on April 3 last. Captain Creak had joined the Society in 1902, and had been a useful Member of its Council from 1905 to 1907. His health had not been good for some years, and he had been unable latterly to take any active part in the Society's affairs, living more or less in retirement at Blackheath.

Captain Creak was the son of the late Commander W. Creak, R.N., and a nephew of Sir H. Havelock, the reliever of Lucknow. He was born in 1835.

His service at sea was in the navigating branch, and he early turned his attention to magnetic survey and the improvement of compasses. He was responsible for much of the preparation for, and subsequent publication of, the magnetic researches of the *Challenger*, and for the instruction of officers on the Arctic expedition of 1875–6.

In 1887 he was appointed Superintendent of the Compass Branch of the Hydrographic Department, and began his long experiments in the construction of liquid compasses designed to replace the old-fashioned compass, which could not stand the vibration of high speeds and the shock of heavy gunfire. After some years he had brought an instrument very near to perfection, but was unable to overcome one difficulty. In the meantime there had been a great demand in the navy for the Kelvin compass, which had been so successfully introduced into the Merchant Service, and the Admiralty could not wait for the perfection of the Creak compass. The Kelvin compass was therefore introduced, but was, after a few years, found defective in the conditions wherein the old compass failed. The final step in the improvement of the liquid compass was not due to Creak, but to a colleague, and there is therefore some danger that the merits of his work, which so nearly reached success and so materially contributed to it, may escape notice.

In 1886, when the question of a resumption of Antarctic Research was being considered by a Committee of the British Association, he had submitted a 'Memorandum on the Advantages to the Science of Terrestrial Magnetism to be obtained from an Expedition to the Region within the Antarctic Circle,' and his consistent support of the proposal for such an expedition was an undoubted help towards its ultimate realization. When Captain Scott's first expedition was being organized he was a useful member of the Committee which considered the programme of its scientific work, and he contributed to the 'Antarctic Manual' the section dealing with the magnetic observations to be undertaken. As President of Section E at the British Association meeting at Southport in 1903 he took as the subject of his address "Terrestrial Magnetism in its Relation to Geography," and he much impressed his colleagues by the alert and business-like way in which he carried through the proceedings at the Committees of his Section.

Personally he was of a singularly modest and unassuming disposition, and was warmly esteemed by all who knew him. He married in 1867, and leaves two sons and one daughter.

CORRESPONDENCE

Telegraphy, Aeronautics and War.

I THINK the answer to your notice of the above-named book must be that the reviewer has inadvertently failed to observe the perfectly legitimate sense in which the volume is entitled 'Telegraphy, Aeronautics and War.' In actual fact it is fairly clearly set forth in the preface that the book consists of a reproduction of addresses, papers, etc., on each of these three separate topics; and if the context is read it will, I think, be seen that even the chance example quoted comes well within the scope of the "War" section—*à propos* of continued war extravagances.

I would submit, too, that your reviewer is not quite justified in a further conclusion—*i.e.* that the omission of Wireless Stations in the Telegraph Map was due to any favouritism of the cable—the fact being that at the time the

volume was produced the information in question could not suitably be published; indeed, nothing but the cable was available for public use.

CHARLES BRIGHT.

The Athenæum,
29 May 1920.

MEETINGS: ROYAL GEOGRAPHICAL SOCIETY: SESSION 1919–1920

Fourteenth Evening Meeting, 17 May 1920.—The President in the Chair.

ELECTIONS.—Captain Richard Leonard Atkinson, M.C.; Captain Lucien Barker-Woden; Mrs. Henry Martin Bull; Francis Edward Butcher; Abraham Rhodes Calvert; Major-General Sir Walter de Saumarez Cayley, K.C.M.G., C.B.; Godfrey W. R. Nightingale Cheesman: Edwin Cleary; John Francis Costello, B.A.; James Crichton; Roger Duncalfe; George Miller Dyott; Herbert Oliver Jones; Calvert Judkins; Lieut. Horace Ross Lowis, I.A.; Lachlan Rose Macphail; Humfrey Trice Martin; Lieut.-Commr. Henry Fitzharding Maxse, R.N.; Lieut.-Colonel Alfred Chevalier Parker, D.S.O.; Frederick Ernest Plummer; Lieut. R. D. Richards; Herbert Sankey, B.A.; George P. Stavrides; Captain Bertram Sidney Thomas; Captain Chorton Orgill Tyrrell, I.A.R.O.; Lieut. Wilfrid Seymour Walker; John Hobson Wragg.

PAPER: The Valleys of Kham. Captain F. Kingdon Ward.

Anniversary General Meeting, 31 May 1920.—The President, Lieut.-Colonel Sir Francis Younghusband, in the Chair.

ELECTIONS.—Herbert Alexander, A.R.W.S.; Captain Hubert Saxton Besant, R.E.; Count Alexis Alexevitch Bobrinskoy; Sir Oswald Bosanquet, K.C.S.I.; Lieut. Charles Taylor Brading; Arthur Vennell Coster; Charles Geoffrey Cotton; James Seymour Crawford; Brig.-General Charles Cunliffe-Owen, C.B., C.M.G.; Prince Kumar S. Fateh Singh of Limbdi; Charles Edwin Harber; Major-General B. Burnett Hitchcock, C.B., D.S.O.; Francis Holmes; Mrs. Isabel Georgina Homewood; Walter C. Stanser Ingles; August F. Miesegaes; Captain Ronald C. Morton; William Washburn Nutting, B.SC.; Lieut. Rhys Ellis Pryce; James Ralston, M.A.; Guy Russell, B.A.; The Rt. Hon. Viscount Sandon; Frederick Hutton Seed; C. Frank Stoop; Frank C. Wheeler; Garnet Oliver Yorke, M.A.

The Hon. Secretary (Mr. A. P. Maudslay) read the minutes of the Anniversary Meeting held on 2 June 1919.

The PRESIDENT: It is now my pleasant duty to present the four Medals and Awards. The Founder's Gold Medal has been awarded to Mr. H. St. J. B. Philby.

Mr. Philby, the Founder's Gold Medal has been awarded to you, with the approval of His Majesty, for your two remarkable journeys in South Central Arabia from the Persian Gulf to the Red Sea. Outside your official duties you took the trouble to train yourself in geographical work and survey, and as a result of your self-training you were able to do very valuable geographical work for us; and it is on that account particularly that we award you the Gold Medal. We hope that you will have much more useful work to do in Arabia, and shall look forward to receiving from you other papers as valuable as those you have already given us. I have special pleasure in handing this Gold Medal

to you, because you belong to the same service as that to which I myself belonged for twenty years.

Mr. H. St. J. B. Philby: I can find no words adequate to express my thanks and my great appreciation of the very high honour which has just been conferred upon me. I feel it is not so much a reward for any work I may have been able to do in Arabia, as an incentive to others to work in the same field, and a token of the very great interest that the Royal Geographical Society has always evinced in Arabia. Arabia, that great desert country, in spite of the fact that it lies between two highways of the world's commerce, the Persian Gulf and the Red Sea, is still but little known to the outside world, and I think that the special interest which this country has in the maintenance of these two highways makes it incumbent on us to strain every nerve to increase our knowledge of all that lies in between them. In that endeavour I think I may safely say it is the Royal Geographical Society which will lead the way, as it has done in so many other parts of the world. May I express the hope, Sir, that your first year of office, having begun with a recognition of the importance of Arabia, may result in as complete a knowledge of what there is in that country as we now have of what was once the Dark Continent of Africa?

The President: The Patron's Gold Medal has been awarded this year to Prof. Cvijić. I am sorry to say that Prof. Cvijić is not able to be here personally, but His Excellency the Minister of the Serbs, Croats, and Slovenes is present.

Your Excellency, I have very great pleasure in handing you this Medal for presentation to Prof. Cvijić. It has been awarded him on account of his many very valuable works upon the geography of the Balkan States and other parts of Europe. We very much regret that Prof. Cvijić is not able to be here this afternoon, but we trust you will convey to him our very best wishes, and our hope that on some future occasion we may have the honour of welcoming him in person.

H.E. The Minister of the Kingdom of Serbs, Croats, and Slovenes: I have the honour, on behalf of M. Cvijić, to express to the Royal Geographical Society his thanks for the Medal which it bestowed upon him. He feels very happy at having merited such a high distinction, the more so as it was given to him by a scientific society of Great Britain. In his letter to me, referring to the Medal, he wrote the following: "I feel very happy at the distinction which has been awarded to me and which I did not expect. I am happy the more so as it came from the Royal Geographical Society. Please express my thanks in the best way." My eloquence is not worthy of this task, and that is why I am simply asking you to accept the sincerest thanks of M. Cvijić, and to believe that he will keep the Medal as the best memory of his scientific career, a career which has not only been recognized by the very high position which he was given to occupy as the Rector of the University of Belgrade, but also by the numerous other recognitions and distinctions accorded to him by home and foreign societies for his scientific works.

The President: The Victoria Medal has been awarded to Colonel Winterbotham for the service he rendered in the initiation and development of scientific methods of artillery survey and the production of high-class maps of inaccessible areas. I have had some personal experience of trying to make even low-class maps of accessible areas, so I can highly appreciate the great work which Colonel Winterbotham must have done in making high-class maps of inaccessible areas. Colonel Winterbotham, you carried on the work in the

discharge of your official duties, but you also showed special initiative and resource in inventing these methods of survey, which were of such great service during the war; and it is especially for this individual inventiveness and resource that we award you this Gold Medal. I have very great pleasure in handing to you the Victoria Medal of the Royal Geographical Society.

Colonel H. ST. L. WINTERBOTHAM: I am sure nobody wishes to recur to any details of the war so happily concluded, and it only remains to me to express my thanks for this very singular honour, not only in my own name, but in that of the brilliant band of young officers, N.C.O.'s, and men who were associated with me under Colonel Jack's command in carrying out these duties.

The PRESIDENT: I am sorry to say that none of the recipients of the other Awards are present here to-day. They are scattered all over different parts of the world. The Murchison Grant is awarded to Miss Czaplicka for her ethnographical and geographical work in northern Siberia. She is not in the country at present. The Cuthbert Peek Grant has been awarded to Mr. A. W. Pearson Chinnery, whom we had the pleasure of listening to a few meetings ago, to assist him in continuing his work in the unexplored parts of New Guinea. He is back, I am glad to say, in New Guinea to carry on more of the excellent work he has already done. The Back Grant has been awarded to Mr. J. M. Wordie, and has been taken in the shape of this very beautiful cup, for his scientific work on the Antarctic expedition of 1914 and 1917 under Sir Ernest Shackleton. He has gone now to Spitsbergen. The Gill Memorial has been awarded to Mr. Reginald Farrer for his journeys in the Chinese borders of Tibet. He is to-day on another of his botanizing expeditions in Upper Burma. If the recipients of these Awards were present here in person, I am sure you would like to extend to them a very hearty appreciation of their good work.

The President then delivered his Anniversary Address, which is printed at p. 1.

The PRESIDENT: We have received the following kind telegram from the Geographical Society of Lisbon: "The Lisbon Geographical Society sends her congratulations Anniversary foundation of your Society and gladly sends delegate represent her on the commemoration. PRESIDENT." Sr. dos Passos Freitas is present here this afternoon.

Sr. DOS PASSOS FREITAS: The Portuguese Geographical Society in sending me here to represent them have asked me to personally convey to you the deepest gratitude, and give you at the same time their congratulations for the wonderful work which you carried out to bring to a speedy and good ending the terrible war that raged in Europe.

The President appointed Mr. John Bolton and Mr. George Dean to be scrutineers of the ballot.

The Annual Report of the Council with the Auditors' Report and the Accounts for 1919 were presented to the meeting.

The meeting proceeded to the election by ballot of the President and Council for the ensuing year (see p. ii.).

Mr. ARTHUR MORO: I have no doubt you have all studied this Council list very carefully, and you will see that certain members of the Council have retired, and I do not think we should wish them to retire without expressing a word of thanks for all they have done during the period of their office. They have been through the trying time of the war and the still more trying time of reconstruction after the war, and I ask you to express your thanks to them in the usual way, by hearty clapping of your hands.